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PART VI

CONTENTS

SECTION—8

TROPICAL AND SUBTROPICAL SOILS

		Pages.
1. S. K. MUKERJI	The soils of West Bengal Part I (Mursidabad) ...	1
2. K. V. S. SATYANARAYANA	Laterite of Kutch ...	17
3. S. D. UPADHAYA	Soil formation under forest cover ...	21

SECTION—9

SOIL CONSERVATION AND MANAGEMENT

1. S. P. S. TEOTIA	Planning for soil conservation in the Damodar Valley ...	27
2. N. D. REGE	A review of soil erosion and its control in New South Wales (Australia) ...	29
3. W. A. PULLAR	Review of soil conservation in the Gisborne-East coast regions of New Zealand ...	33

SECTION—10

LAND CLASSIFICATION AND EVOLUTION

1. S. P. S. TEOTIA	Land classification surveys for soil conservation planning in the Damodar Valley ...	41
2. R. R. AGARWAL, C. L. MALHOTRA AND C. P. GUPTA	Soil classification and soil mapping in Naini Tal Tarai ...	46
3. M. RIM	Evolution cycles observed in desert fringe land ...	61
4. M. SANYASI RAJU AND D. JOHN DORAIRAJU	The Geochemistry of Madras soils ...	66
5. B. K. MUKERJI	Soil classification in relation to agricultural development...	75

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SECTION—8

TROPICAL AND SUBTROPICAL SOILS

THE SOILS OF WEST BENGAL PART I (MURSHIDABAD)

By S. K. MUKERJI [1]

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(Received on 18th October, 1954)

The district of Mursidabad is in the North-Eastern corner of the Gangetic West Bengal, situated within the parallels of 23° 43′ and 24°52′ North latitude and 87° 49′ and 88°44′ East longitude. It has an area of 2095 square miles.

In general the district is an alluvial plane with the Bhagirathi, running from North to South. The part on the South-West is slightly undulating having a gentle slope from West to East. The land between the rivers Babla and Bhagirathi, right from their confluence on the border of Mursidabad and Burdwan, up to the Bans or Paglu river in police station Suti, which joins the Bhagirathi on the North of the town of Jangipore, is a higher land and is moderately undulating. The highest area is in the police station of Sagardighi. The land becomes less undulating on the North of the railway station Gankar. The land is almost level in Samsergung and Suti police stations. In the police station Farakka, the land is sloping from the West hilly tracts towards the East. The portion West of the Bagdoba river is gravelly, being an extension of the upper Gondwana tract (Mahadevas) from the district of Santhal Parganas.

The eastern part of the Bhagirathi, has a gentle slope from North to South. The central part is a flat land. The southern portion occupying the South of police stations of Hariharpara, Naoda and the eastern part of Beldanga is a shallow basin, wherein, all the rivulets of the central flat lands drain in. The only outlet of this area is through the river Suti, which drains the excess in the Jalangi. There are several natural depressions apart from these, formed by the river valleys and drainage lines.

1. The soil work was taken up under the initiative of Sri K. Sen, I. C. S.

Schematic type of soil survey[2] was adopted. Preparation of schematic soil map from spot observations was undertaken. The profiles were studied at 6 mile grid-intersection points. The pits were dug in the vicinity of villages situated near the grid-intersection points, and soil samples were obtained from the profile to a depth of 4 ft.[3] Thus 65 profiles were examined, and soil samples collected from them horizonwise. Wherever the horizon differentiations were not clear cut or layers could not be distinguished, samples were obtained from each foot depth.

Soil samples passing a 2-mm seive were used for analysis in the laboratory. Mechanical analysis was carried out by the pipette method, after removing lime with HCl. The analysis of "A" complex[4] was made by the method of extraction of the Agricultural Education Association.[5] The electrometric method using glass electrode was used to determine pH values and conductivity was determined to estimate the amount of soluble salts. Exchangeable bases were estimated by the method of Williams.[6] Since most of the soils examined were calcareous this has been expressed as bases sol in N/2 acetic acid. Other items were analysed by the methods given in the book of Wright.[7]

METEOROLOGICAL DATA

The records of monthly rainfall with those for temperature and humidity for Mursidabad are given in Table I. These are average of ten years, 1938-47 and the recording station is Behrampore.

TABLE I

Months	Mean temperature °F	Mean Average Max. and Min. temperature. °F.		Rainfall in inches.	Average Mean of 8 hrs.	Humidity Mean of 17 hrs.
January	66·1	78·5	53·7	0·78	78·2	51·2
February	69·1	82·4	55·8	0·84	70·3	40·2
March	78·5	93·2	64·6	0·77	62·4	31·7
April	85·3	98·3	72·9	1·71	69·0	39·5
May	87·6	98·1	77·1	3·02	75·7	55·0
June	86·5	94·0	78·8	7·50	82·3	74·0
July	84·5	90·3	78·7	15·01	86·9	80·2
August	84·4	90·1	78·8	15·65	86·1	79·7
September	84·8	91·1	78·5	9·60	83·7	77·7
October	81·4	89·3	78·5	5·16	78·3	69·8
November	74·4	85·1	63·7	0·24	75·8	59·6
December	67·6	79·5	55·7	0·19	75·9	55·7
Average	79·2	89·2	69·3	60·47	75·06	59·54

2. Soil Survey Manual. No 18. Department of Agriculture, U. S. A. 1951 pp. 15, 21, etc.
3. *Ibid* pp. 171.
4. The Principles of Soil Science by De Sigmond, 1938, pp. 84-116.
5. A. E. A. 1931.
6. Williams. R. Determination of exchangeable calcium in calcium carbonate free soils. Jour. Agric. Sci. **18**, 439 (1928)
7. Wright, C. H., Methods of Soil Analysis. Thomas Murby & Co. London, 1939.

Highest average temperature in the month of May was recorded in the year 1942, which is 111°F.

Average rainfall of the district is 60·47 inches.
Average temperature is 79·2°F.
Average Barometric pressure is 29·92 inches.
Height of the barometric cistern above mean sea level is 62.
Langs factor is 70 mm per degree centigrade.
Myers N.—S.— Q. is 184.

It may be seen that the rainfall is well over 3 inches on the average from Mayto October. The highest rainy months are July and August. The early rainfall from the month of May has determined the cropping practice of this district. The rains start from April and it's intensity goes on increasing reaching highest in August. The conditions, therefore, are suitable for growing jute, aus paddy, early aman paddy and sugarcane. The acerage under each of these crops are given below.

Aus	Aman	Sugarcane	Jute
3,42,882.21	4,35,254.27	11,794.35	33,257.22 acres

This district has a considerable area under pulses and rabi cereals. The winter rains amounting on the average to 2 inches coupled with low humidity and temperature is helpful for rabi cereals, especially wheat and barley. The area under wheat is about 42,169·37 acres and of barley 27,625·90 acres. With increasing facilities of irrigation from the Mor project, the area under rabi cereals is expected to go up considerably.

This district is famous for it's good quality mango. The mango orchards occupy 27,824·31 acres. Of specific crops of importance are the extensive mulbery cultivation which occupied an area of 1,448·73 acres in 1944-45 and now according to the census of 1951 has increased to 17,000 acres and Ganja, the cultivation of which is increasing. Gram, masur and khesari, which occupy, 1,33,853·74, 69,623 and 49,291.4 acres, are the more commonly grown pulses.

SOILS

The Lang's factor is 70. This favours the formation of brown earth group of soils. The Mayer's N-S Quotient is 184, which favours the formation of chestnut brown steppe soils and the Tshernosems. The following are the natural soil regions found in this district, formed as a result of the physical features, the watersheds and the climate.

Soil Family :—(*a*) Vindhyan alluvium.
(*b*) Ganga alluvium.

In the family of the Ganga alluvium four soil associations occur. They are,

(1) Ganga riverine lands.
(2) Ganga flatlands.
(3) Ganga uplands.
(4) Ganga lowlands.

In the family of Vindhyan alluvium three soil associations occur. They are,

(5) Vindhyan riverine lands
(6) Vindhyan flatlands.
(7) Vindhyan highlands.

A brief descrsption of the above soil families and associations are given here, and a tentative demarcation is given in the accompanying Schematic map.

The nomenclature of the family of "Vindhyan alluvium" of soils, has been coined, on the basis of their origin and geographical situation. This family of soils has been formed from the alluvium brought down by the rivers, which have their origin in the North-Eastern extension of the system of Vindhya hills (Rajmahals). The hilly tract, where these rivers have originated, belongs geologically to the upper Gondwana (Mahadevas) and Gneiss of all ages. These rivers then flow through a region of low level laterites (sub-recent) and descend down on the alluvial plains of the adjoining district of Birbhum and then cross into Mursidabad to join the Ganges.

All such soil associations, which have originated from the Gangetic alluvium have been given the family name of Ganga Alluvium.

The soils of each of these families have been subdivided into soil associations. Topography, mode of formation and the design of development of the profiles are the major considerations in setting up of four profile groups or associations in the family of Ganga alluvium and three profile groups in Vindhyan alluvium.

1. Ganga riverine lands.—Soils on recent alluvial fans, flood plains or other secondary deposits having undeveloped profiles underlain by unconsolidated material. These profiles show no accumulation of clay or lime in the sub-soil resulting from the downward movement of particles from the surface horizon. The deposition of alluvium in different layers having different mechanical composition is evident. The profile effervesces strongly giving proof of the presence of calcium carbonate throughout it's depth.

2. Ganga flat lands.—Soils on young alluvial fans, flood plains or other secondary deposits, having undeveloped profiles, underlain by unconsolidated meterial. These profiles show slight compaction and slight accumulation of clay in the subsoils as a result of leaching from the surface horizons.

3. Ganga uplands.—Soils on older alluvial fans, alluvial plains and terraces, having a very slightly developed profiles. These profiles have a moderate accumulation of clay in them and a high concentration of lime in the form of concretions, in the sub-soil, as a result of continued movement of calcium from the surface horizons.

4. Ganga lowlands.—Soils on lower plains and depressions, having accumulation of clay in the sub-soil, underlain by unconsolidated material. These are clay pan soils, in which the pans are relatively near the surface and relatively impervious to the downward moverrent of water. This is underlain by a horizon which, at places are lime or lime-iron and do not soften or disintegrate in water. This is similar to lacustrine deposits.

5. Vindhyan riverine lands.—Soils on older alluvial fans, alluvial plains or terraces underlain by unconsolidated materials. Soils of these profile groups have been formed from the weathering of hard acid or basic igneous rocks like gneiss of all ages and of Gondwana tracts in Bihar and have been transported by a series of rivers and deposited in alluvial plains or terraces.

6. Vindhyan flat lands—Soils on older plains or terraces, having moderately developed profiles with unconsolidated material. These profiles have moderate accumulation of clay or higher concentration of lime in the subsoil as

a result of leaching from the surface horizons. The soil layer of clay is interspersed with iron or iron-manganese, rounded concretions, which occur at a depth of 2-3 ft. indicating waterlogging for a considerable period of the year.

7. *Vindhyan high lands*—Soils on older plains or terraces, having subsoil layers of clay rich in sesquioxides, usually underlain by dolomites. The subsoil layers are clayey with lime iron or iron cemented, which makes those relatively impervious to the downward movement of water.

One typical profile from each of these profile groups or soil associations, together with their soil analysis is described below. These profiles have been taken as representative mapping units, for each soil association.

1. GANGA RIVERINE LANDS

Morphology

Horizons	Depth in inches	Description
?	0-12	Olive in colour 5Y4/3. Non-sticky, fine sandy loam, single grained, loose, soft, calcareous, moist, moderately alkaline and full of plant roots.
?	12-15	Olive gray 5Y4/2, Loamy sand, non-sticky. single grained, loose, calcareous, more moist, moderately alkaline and plant roots present.
?	15-29	Gray 5Y4/4, sandy, non-sticky, calcareous, loose, very moist, single grained, moderately alkaline and plant roots present.
?	29-33	Olive 5Y4/3, loamy sand, floury in touch, more moist, thin platy, calcareous, moderately alkaline, and few roots are present.
?	33-40	Olive gray 5Y4/2, fine sandy, calcareous, non-sticky, structureless, no plant roots present.
?	40-48	White fine sand 5Y8/1, calcareous, very moist,. moderately alkaline, loose soil, and no plant roots.

Mechanical and general composition

(per cent. oven dry basis)

Laboratory number	R-204	R-205	R-206	R-207	R-208	R-209
Depth in inches	0-12	12-15	15-29	29-33	33-40	40-48
Coarse sand	0·40	0·13	0·15	0·08	0·14	1·23
Fine sand	59·04	67·68	81·19	56·35	78·36	88·35
Silt	22·55	18·55	8·10	29·35	11·40	1·75
Clay	13·95	12·35	6·00	11·80	6·55	4·35
Air-dry-moisture	1·60	0·79	0·29	1·04	0·49	0·34
pH	8·58	7·98	8·04	7·92	7·82	7·92
Carbon	0·29	0·29	0·15	0·30	0·12	0·05
Nitrogen	0·03	0·04	0·02	0·03	0·02	0·01
Soil colour at field capacity	5Y4/3	5Y4/2	5Y4/4	5Y4/3	5Y4/2	5Y8/1

Chemical composition of "A" complex

(per cent. oven dry basis)

Sesquioxides	14·40	8·48	7·64	9·61	5·53	5·23
Fe_2O_3	4·50	3·56	3·20	4·04	2·40	2·28
Al_2O_3	9·90	4·92	4·44	5·57	3·13	2·95
CaO	4·50	4·05	4·26	4·56	4·46	3·46
P_2O_5	0·14	0·11	0·11	0·12	0·12	0·11
K_2O	0·37	0·69	0·57	0·49	0·48	0·42
Water sol salts	0·12	0·11	0·10	0·12	0·10	0·09
N/2 acetic acid sol bases m.e.	156·4	144·4	164·4	184·4	171·0	152·0
N/2 acetic acid sol CaO m.e.	128·2	124·6	133·8	126·4	141·8	128·0

These soils have been formed as a result of deposits of Gangetic alluvium, received almost annually from the rivers Ganges (Padma and Bhagirathi). The morphology indicates, that this group of profiles are of a very recent origin. Soil horizons have not yet got sufficient time to develop. The soil profiles throughout their depths are calcareous, and predominate in fine sand. There is absolutely no indication even from chemical analysis of any effect of weathering and subsequent leaching down of the weathered products in the lower layers. The profiles contain more soluble salts than the soil associations two or three, but the concentration of soluble salts are not so high as to be prejudicial to crop growth. These soils are rich in potash and phosphates, but poor in organic matter and nitrogen. Each layer in the profile is different from the rest and is maintaing it's individual character.

Inspite of their open nature due to their content of a high proportion of sand, these soils have a fairly good moisture status. This is due to the high percentage of finely divided calcium carbonate present in these soils. The amount at most of the places examined are about ten per cent.. The permeability of these soils are very high and so is root penetrability. These soils are highly suitable for growing sugarcane.

2. GANGA FLAT LANDS

Morphology

Horizons	Depth in inches	Descriptions
A ?	0-12	Olive in colour 5Y4/3, sandy loam, fine crumb, slightly sticky, friable, calcareous, moist, permeable, mildly alkaline and roots present.
A ?	12-21	Pale olive 5Y5/3, sandy loam fine crumb structure, slightly more sticky, friable, calcareous, moist, permeable, moderately alkaline, and plant roots are present.
B ?	21-41	Oiive 5Y4/3, loam, crumby (medium), friable, calcareous, moist, a few plant roots, permeable and moderately alkaline.
B ?	41-48	Olive 5Y5/3, medium crumb, loam, friable, calcareous, softer than above moderately alkaline and a few plant roots are present.

Mechanical and general composition
(per cent. oven dry basis)

Laboratory number.	R-145	R-146	R-147	R-148
Depth in inches	0-12	12-21	21-41	41-48
Coarse sand	0·18	0·14	0·27	0·44
Fine sand	48·61	47·39	37·50	38·68
Silt	38.80	39·75	43·85	40·95
Clay	10·30	10·50	14·05	15·10
Air-dry-moisture	0·70	1·80	4·00	2·70
pH	8·44	8·50	8·48	8·50
Carbon	0·50	0·47	0·30	0·41
Nitrogen	0·042	0·046	0·046	0·049
Soil colour at field capacity	5Y4/3	5Y5/3	5Y4/3	5Y5/3

Chemical composition of "A" complex
(per cent. oven dry basis)

Sesquioxides	7·45	9·82	18·4	14·32
Fe_2O_3	3·42	4·68	6·75	5·96
$Al\ O_3$	4·03	5·14	11·65	8·36
CaO	4·35	3·90	2·80	6·40
K_2O	0·47	0·54	1·01	0·80
P_2O_5	0·14	0·13	0·11	0·12
Water sol salts	0·097	0·049	0·055	0·050
N/2 acetic acid sol bases in m. e.	141·6	146·8	89·6	209·8
N/2 acetic acid sol CaO m. e.	126·0	155·2	82·2	188·8

The coined name Ganga flat lands has been given to this soil association due to it's relief and topography. This area occurs in a flat topography, south of the Ganga riverine lands. It has the Padma on the east and Bhagirathi on the west. This soil association is now out of reach of floods and has got a chance of undergoing some degree of weathering. The characteristics of Ganga alluvium, *i.e.*, the existence of finely divided calcium carbonate, in a powder form which is distributed throughout the profile at random exist. Due to the alkaline nature of the profile and a lack of organic matter, the leaching of calcium is not evident. The potassium, sesquioxides, especially aluminium and clay all show some sign of leaching from the upper layers and accumulation at the lower ones. The above indicates the older nature of this soil association compared to the riverine lands.

An excellent permeability and water retention capacity coupled with the climatic benefit of summer rains makes this area, ideally suitable for sugarcane plantations. This area at present grows aus paddy and jute in kharif and pulses in rabi, but the land can be made to give more money if a cash crop like sugarcane is developed in this region.

The potash and phosphate resources are quite high to be supplemented in near future. The nitrogen is moderate and the buffer capacity of these soils are very high so that reduction of pH by application of ammonium sulphate is almost a remote possibilty. The state high tension line passes through this area and if suitably planned the possibility of development of sugarcane industry is good.

3. GANGA UPLANDS

Morphology

Horizons	Depth in inches	Description
?	0-8	Olive 5Y4/3, clayey, slightly sticky, plastic, firm when moist, hard when dry, fine sub-angular blocky, mildly alkaline, moist, very slowly permeable and abundant plant roots.
?	8-18	Dark olive gray 5Y3/2, clayey, sticky, very plastic, firm when moist and hard when dry, fine sub-angular blocky, mildly alkaline, more moist, small brownish black cocretions, diameter 0·2 to 0·4 cm, in irregularly shaped pellets, mildly alkaline, slowly permeable and a few plant roots present.
Lime horizon	18-28	Olive 5Y6/4, clayey, sticky, plastic, less firm when moist and less hard when dry, medium crumb structure, moderately alkaline, contains calcium carbonate concretions in irregular forms of size of pea, low permeability and a few very thin roots present.
Lime horizon	28-37	Pale olive yellow 5Y6/6, clayey, stightly sticky, plastic, firm when moist, hard when dry, medium crumb, moderately alkaline, contains free calcium carbonate, lime concretions ½ inch to 2 inches in diameter of irregular shape, have accumulated and has formed almost a pan like deposit admixed with clay. This layer is moist and no plant roots are present.

Mechanical and general composition

(per cent. oven dry basis)

Laboratory number ...	R-137	R-138	R-139	R-140
Depth in inches ...	0-8	8-18	18-28	28-37
Coarse sand ...	0·46	0·29	0·55	0·87
Fine sand ...	22·25	20·06	20·26	17·97
Silt ...	21·15	22·50	26·65	19·75
Clay ...	49·85	52·00	46·95	50·35
Air-dry-moisture ...	7·11	7·63	8·79	10·73
pH ...	7·48	7·80	8·22	8·30
Carbon ...	0·46	0·32	0·34	0·35
Nitrogen ...	0·035	0·041	0·039	0·032
Soil colour at field capacity	5Y4/3	5Y3/2	5Y6/4	5Y6/6

Chemical composition of the "A" complex.

(per cent oven dry basis)

Sesquioxides ...	14·66	14·04	13·04	14·76
Fe_2O_3 ...	5·08	4·52	4·84	5·16
Al_2O_3 ...	9·58	9·52	8·20	9·60
CaO ...	1·31	1·25	1·54	2·52
K_2O ...	0·13	0·19	0·23	0·35
P_2O_5 ...	0·053	0·036	0·040	0·037
Water sol salts ...	0·067	0·042	0·084	0·100
N/2 acetic acid sol bases m.e.	22·00	21·20	31·40	59·80
N/2 acetic acid sol CaO m.e.	16·00	16·00	31·20	48·80

The coined name Ganga uplands has been given to this soil association due to it's occurence in a comparatively higher topography. This tract of land is the most consolidated amongst the Gangetic family of soils, found in this district. The river Bhagirathi rarely swings to the right and break new lands due to the more stable nature of these soils. Similarly the rivulets which have their origin in and beyond the south western part of the district, can scarcely penetrate it to meet the Ganges. They perhaps find it too difficult to break through this barrier of stiff clay and Kankers (dolomite) and either cause waterlogging in the south western part or somehow trickle their water through the only outlet in this barrier, the Babla.

This profile group is characterised, by it's clayey nature and lime cocretions with a lime horizon. The sesquioxide and the clay are immobile. The top two layers do not effevescec at most of the places. Calcium carbonate as indurated concretions are found only in the third and fourth layers, which has accumulated due to leaching from the top horizon. The high clay content coupled with the rise of the water table almot to the surface during rains makes this type of soil suitable for aman paddy. Phosphate content of this scil association is low and must be supplemented. Potash is adequate and nitrogen low. The soil is adequately buffered and addition of a mixture of ammonium sulphate and super phosphate may be used, without any detrimental effect on the soil.

4. GANGA LOWLANDS

Morphology

Horizon	Depth in inches	Description
?	0-14	Very gray colour 5Y3/1, highly clayey, very sticky, plastic, firm consistency, very hard and cracks when dry, coarse angular blocky, mildly alkaline and plant roots are present.
?	14-29	Black in colour 5Y2/2, highly clayey, very sticky, plastic, firm, very hard and cracks when dry, medium angular blocky, mildly alkaline and a few thin plant roots are present.
Lime horizon	29-34	Dark olive gray 5Y3/2, clayey, slightly sticky, slightly plastic, firm when moist and slightly hard when dry, medium granular structure, free calcium carbonate present, lime concretion rough and irregular forms of sizes varying in length from $\frac{1}{2}$ inches to about 3 inches, mildly alkaline and few thin roots are present.
?	34-48	Light gray 5Y7/1, fine sand, slightly calcareous, single grained, non-sticky, non-plastic, loose, mildly alkaline and no roots present.

Mechanical and general composition

(per cent. oven dry basis)

Laboratory number	...	R-41	R-42	R-43	R-44
Depth in inches	...	0-14	14-29	29-34	34-48
Coarse sand	...	0·38	0·16	1·42	10·44
Fine sand	...	2·08	1·39	11·07	59·18
Silt	...	14·60	17·40	14·75	3·95

Clay ...	73·60	72·10	55·25	17·30
Air-dry-moisture ...	6·89	6·75	5·39	1·85
pH ...	8·20	7·68	7·70	7·80
Carbon ...	1·12	0·77	0·72	0.26
Nitrogen ...	0·07	0·07	0·05	0·023
Soil colour at field capacity	5Y3/1	5Y2/2	5Y3/2	5Y3/1

Chemical composition of "A" complex

(Per cent. oven dry basis)

Sesquioxides ...	22·71	23·34	17·95	10·37
Fe_2O_3 ...	8·12	8·62	7·14	4·52
Al_2O_3 ...	14·59	14·72	10·81	5·85
Ca O ...	0·99	1·02	2·28	0·67
K_2O ...	0·19	0·36	0·03	0·13
P_2O_5 ...	0·067	0·092	0·091	0·094
N/2 acetic acid sol bases m.e.	36·09	36·89	78·64	23·63
N/2 acetic acid sol CaO m.e.	24·70	27·02	65·31	16·50
Water Sol salts	0·59	0·45	0·10	0·074

This association occurs in a saucer shaped shallow depression, which is situated in the south of the district on the east of the Ganges. The drainage water from the adjoining soil associations accumulates into it. The finer materials brought down by these washes settle over this area. The excess of water is drained by the river Suti into the Jalangi. This association is mainly a lacustrine deposit.

This profile group is characterised by profiles having a heavy clay uppet horizon, followed by a sub-soil less heavy and containing indurated dolomvier concretions cemented with clay over a Gagetic riverine type of profile.

The soil on the surface in highly clayey and offers great resistance to mechanical appliances. It is very difficult even for a bullock cart, to move in this area when the soil is moist. The wheels of the cart very easily sink deep and get stuck up in the clay and it becomes almost impossible to take it out. This behaviour of the soil has given it a local name "Kalantar" meaning the area of death. Otherwise the soil is quite rich in all plant nutrients. The depth of standing water during the rainy season varies from 3 to 5 feet. Deep water aman paddy is commonly grown wherever possible. During the winter this area gets dried up and soil cracks as the dehydration of the clay of the soil progresses. Pulses are taken at places which dry out first.

These soils are saline and therefore get very unkind and dry up quickly at the surface as soon as the surface water receeds and develop deep cracks. The high salt concentration in the soils of this association though not prejudicial for paddy does not allow a good rabi crop to grow. It is grown only in patches having low salt concentrations.

5. VINDHYAN RIVERINE LANDS

Morphology

Horizons	Depth in inches	Descriptions
?	0-13	Dark yellowish brown 10YR4/4, clay loam, medium platy, sticky, plastic, friable, very hard when dry, neutral and plant roots present in abundance.

?	13-25	Yellow 10YR7/4, sandy loam, single grained slightly sticky, slightly plastic, very friable, soft, mildly alkaline and plant roots present.
?	25-32	Light yellowish brown 10YR6/4, clay loam, single grained, slightly sticky, slightly plastic, friable, neutral and plant roots present.
?	32-45	Yellowish brown 10Y5/4, coarse sand, loose and mildy alkaline.

Mechanical and general composition

(per cent. oven dry basis)

Laboratory number ...	R-57	R-58	R-59	R-60
Depth in inches ...	0-13	13-25	25-32	32-48
Coarse sand ...	7·96	4·98	3·37	27·56
Fine sand ...	34·77	45·64	45·24	63·23
Silt ...	27·30	28·50	16·75	0·50
Clay ...	30·40	18·30	30·25	8·25
Air-dry-moisture ...	3·35	2·57	3·98	0 09
pH ...	7·20	7·60	6·70	7·40
Organic carbon ...	0·242	0·093	0·173	0·054
Nitrogen ...	0·021	0·018	0·029	0·008
Soil colour at field capacity...	10YR4/4	10YR7/4	10YR6/4	10YR5/4

Chemical composition of "A" complex

(per cent. oven dry basis)

Sesquioxides ...	13.37	6·40	11·50	3·71
Fe_2O_3 ...	5·44	3·28	5·68	2·04
Al_2O_3 ...	7·93	3·12	5·82	1·67
CaO ...	0·60	0·31	0·55	0·27
K_2O ...	0·42	0·11	0·12	0·23
P_2O_5 ...	0·027	0·029	0·077	0·045
Water sol salts ...	0·025	0·029	0·077	0·045
N/2 acetic acid sol bases m.e.	14·40	8·00	10·80	4·40
N/2 acetic acid sol CaO m. e.	9·32	7·20	8·80	4·40

This association of soils occurs in the flood fans of the rivers, which have their origin in the rocky regions of Bihar, beyond the alluvial plane and the gravelly areas of the Birbhum district. These rivers bring down annually weathered products formed in the regions occupied by gneiss of all ages and the Gondwana series (Mahadevas) and deposit them in these flood fans. These rivulets also flow through the lateritic region of Birbhum district and therefore the alluvium brought down by these rivers and deposited by them are of mixed origin.

The profile characteristic of this soil association is, that it should contain distinct sand layers, which should be of coarse nature and non-calcareous, sandwitched between clay loams or loams or silty loams or sandy loams. There should be no concretion in a regular layerwise, though occasional lime concretions in the form of yellowish, irregular shaped dolomite, sparsely scattered in the profile may be met with. These should not be taken as a characteristic of the profile group for they occur at random and perhaps have been carried down by the riverwash from the adjoining areas of Birbhum district, which are rich in dolomites. The

rich colour of the soils may be ascribed to their iron content, though ferro or ferromanganese concretions are absent, indicating an abscence of waterlogging of the area for any considerable part of year.

This area grows transplanted aus, potato, sugarcane and pulses. Irrigation is a necessasity for the area and the soils are quite permeable and salt free so that there wont be much damage to the soil if intensive irrigation is planned. Loss by seepage, however, must be taken into consideration, which at places may be considerable. The nutrient status is on the average too low. Phosphatic and potassic manuring may be recommended for this tract. Nitrogenous manuring, however, may be made in the form of organic manures or basic nitrogenous artificials instead of ammonium sulphate. The buffer capacity of these soils are low and ammonium sulphate should be cautiously used. Ammonium sulphate when used may always be compounded with phosphate for all crops and with potash in addition when used for potash loving crops like potato or jute.

6. VINDHYAN FLATLANDS

Morphology

Horizons	Depth in inches	Description
?	0-10	Yellowish brown 10YR5/4, clay loam, medium platy, slightly sticky, plastic, friable, slightly hard, permeable, slightly acid and plenty of roots.
?	10-22	Dark yellowish brown 10YR4/4, clayey, plastic, moderately permeable, medium angular blocky, plastic, firm, hard when dry, neutral, fewer plant roots and a few brown concretions as irregularly small pellets.
?	22-34	Dark yellowish brown 10YR4/4, clayey, medium angular blocky, sticky, plastic, slowly permeable, firm hard when dry, neutral, a few plant roots, very few lime concretions of irregularly shaped of all sizes, and brown small concretions 1 cm to 3 cm in diameter.
?	34-48	Light yellowish brown 10YR6/4, clayey, coarse angular blocky, very sticky, plastic, very firm, very hard when dry, very slow permeability, medium acid, plant roots nil., Stray dolomite concretions of irregularly rounded shape scattered in the profile.

Mechanical and general composition

(per cent. oven dry basis)

Laboratory number	...	R-69	R-70	R-71	R-72
Depth in inches	...	0-10	10-22	22-34	34-48
Coarse sand	...	2·62	2·05	2·23	1·15
Fine sand	...	30·33	27·86	26·02	21·55
Silt	...	25·70	23·25	23·00	24·50
Clay	...	33·15	42·00	43·75	47·26
Air-dry-moisture	...	5·82	4·89	5·20	6·04
pH	...	6·10	6·60	6·62	6·08

Organic carbon	...	0·37	0·15	0·11	0·095
Nitrogen	...	0·021	0·025	0·020	0·007
Soil colour at field capacity	...	10YR5/4	10YR4/4	10YR4/4	10YR6/4

Chemical composition of the "A" complex

(per cent. oven dry basis)

Sesquioxides	...	9·97	15·25	14·20	15·50
Fe_2O_3	...	4·16	5·04	4·84	4·64
Al_2O_3	...	5·81	10·21	9·36	10·96
CaO	...	0·52	0·38	0·66	0·67
K_2O	...	0·12	0·15	0·18	0·05
P_2O_5	...	0·051	0·017	0·014	0·015
Water sol salts	...	0·08	0·037	0·036	0·061
N/2 acetic acid sol bases m. e.	...	13·6	9·6	9·2	12·4
N/2 acetic acid sol CaO m. e.	...	12·8	8·4	8·0	11·2

This soil association occupies a flat topography, out of reach of the floods, from which the riverine lands suffer. Weathering has not proceeded to a degree, so that soil horizons can be formed. In the soil profile, layers are easily distinguishable, by their colour, moisture content and other physical characteristics. There is no marked illuviation of sesquioxides in the lower layers. The distribution of calcium or potassium in the profile do not show any indication of leaching from the top and accumulation in the lower layers. The composition of "A" complex indicated a typical old alluvial profile, for the composition of each layer is independent of the other. Clay, however, indicates that the process of leaching has started. It is 35·15 per cent. on the surface which progressively increases upto 47·26 per cent. at the lowest layer. Since the exchangeable bases do not increase simultaneously with the increase of clay in the sub-soil, it may be deduced that the migration takes place after it has become a hydrogen clay. The pH of the different layers of the profiles also substantiate this. There are occasional dolomite concretions of fairly big sizes occuring at random in the soil profile. Their modes of distribution give rise to the feeling that these are flood borne deposits and did not occur *in situ*. Brown iron concretions do occur in the lower layers due to the water table rising in the profile during rains and partial waterlogging of the depth for some months during each year.

The profiles of this association are characterised by a heavy subsoil, occurrence of brown concretions in layers below, occurrence of isolated dolomite concretions, no free calcium carbonate to effervesce, and an illuviated layer of clay below. Insect holes are plenty.

Aman paddy, wheat, potato, sugarcane, gram and vegetables are the main crops grown in this area wherever water is available. It is poor in nitrogen, potash, phosphoric acid and extremely poor in organic matter. The low base satatus of the soil indicate that nitrogen should preferably be given in organic form and acid forming fertilisers should be avoided. Phosphate may be given, preferably as bone meal, though superphosphate is not contra indicated. Potash level is also low and therefore potato crop must be supplemented with potash for greater production.

7. VINDHYAN HIGHLANDS

Morphology

Horizons	Depth in inches	Descriptions
A?	1-4	Light yellowish brown 10YR6/4, loam, angular blocky, sticky, plastic, friable, plant roots many, hard when dry, slightly acid and permeable.
B?	4–12	Yellowish brown 10YR5/6, clayey, angular blocky, more sticky, plastic, friable, abundant plant roots, hard when dry, mildly alkaline, permeable and contains irregularly shaped dolomites, few in number.
B?	12–34	Dark yellowish brown 10YR4/4, clayey, zone of accumulation, angular blocky, very sticky, very plastic, firm, few plant roots, very hard when dry, mildly alkaline, very slowly permeable and dolomites 2 to 3 inches long are present.
B?	34-48	Yellowish brown 10YR5/4, coarse, clayey, angular blocky, very sticky, very plastic, firm, plant roots few, very hard when dry, mildly alkaline, slowly permeable, better than the upper layer and dolomites of sizes 3 to 4 inches in length.

Mechanical and general composition

(per cent. oven dry basis)

Laboratory number	...	R-160	R-161	R-162	R-163
Depth in inches	...	0–4	4–12	12–34	34–48
Coarse sand	...	3·13	4·39	9·69	17·40
Fine sand	...	50·74	39·22	30·40	24·43
Silt	...	28·60	27·30	24·90	22·40
Clay	...	19·30	30·05	36·80	35·90
Air-dry-moisture	...	1·82	2·62	3·79	4·69
pH	...	6·04	7·10	7·62	7·30
Organic carbon	...	0·516	0·189	0·164	0·151
Nitrogen	...	0·058	0·038	0·030	0·029
Soil colour at field capacity	...	10YR6/4	10YR5/6	10YR4/4	10YR5/4

Chemical composition of the "A" complex

(per cent. oven dry basis)

Sesquioxides	...	7·27	12·09	17·65	17·90
Fe_2O_3	...	2·60	3·96	5·44	5·84
Al_2O_3	...	4·67	8·13	12·21	12·06
CaO	...	0·29	0·39	0·48	0·57
K_2O	...	0·42	0·42	0·51	0·50
P_2O_5	...	0·05	0·02	0·04	0·02
Water sol salts	...	0·016	0·036	0·038	0·031
N/2 acetic acid sol bases, m.e.	...	8·80	11·20	12·80	14·80
N/2 acetic acid sol CaO m.e.	...	4·20	7·00	8·80	9·40

This soil association occupies almost an uniform stretch of land on the northern half of Vindhyan family of soils.

The profiles of this group are characterised by the presence of a leached horizon on the top and a zone of accumulation at the bottom. The evidence of leaching of clay and sesquioxides are quite prominent. The evidence of leaching of aluminium, iron, calcium and potassium and their accumulation in the lower horizons, however, can be detected by chemical analysis and so is the degree of leaching of bases to the lower horizons.

There exist isolated dolomite concretions of fairly big size throughout the profile. A few *kutchha* wells were examined in this area. They revealed that a layer of dolomite is commonly found to occur between 8 to 12 feet. The thickness of the layer varied from 6 inches to 18 inches in different localities. Some concretions from the layer were brought up from inside these *kutchha* wells at a few place and examined. These concretions were found admixed with a high proportion of coarse sand and a low proportion of clay.

The sub-soil water when rises during rainy season crosses this layer and becomes saturated with lime, which prevents the soil profile to become acidic. This perhaps may be one of the reasons, for the surface to remain slightly acidic, when the sub-soils are neutral to mildly alkaline. Under these conditions of alternate leaching and rise of calcium in the soil, that this type of profile group is formed.

The clay fraction has leached down along the profile and has accumulated in the third and the fourth layers. The coarse sand on the other hand is also present in larger amounts with depth. These two factors are responsible for keeping the different soil horizons, quite permeable, inspite of their high clay content.

The area occupied by this soil association is well known for its high soil fertility. The area is well suited for irrigation, a lack of which, has hindered fuller exploitation of the soil resources.

In the accompanying soil map, the boundaries of soil associations have been shown either by the river lines or by the boundary lines of the police stations. Where this has not been possible, a straight line has been drawn between the observed points to indicate the tentative soil boundaries.

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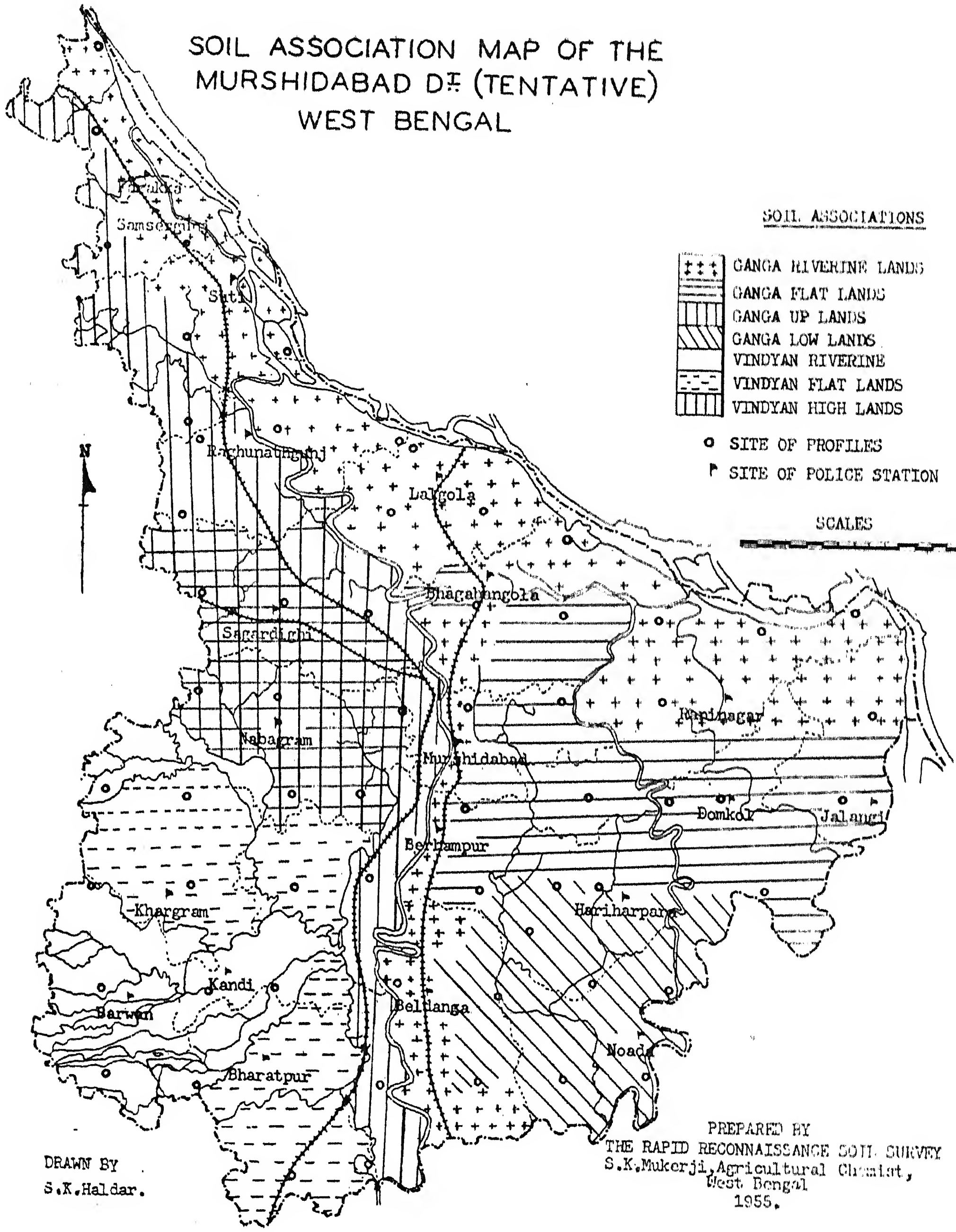
SOIL ASSOCIATION MAP OF THE
MURSHIDABAD D.T. (TENTATIVE)
WEST BENGAL
SOIL ASSOCIATIONS
GANGA RIVERINE LANDS
GANGA FLAT LANDS
GANGA UP LANDS
GANGA LOW LANDS
VINDYAN RIVERINE
VINDYAN FLAT LANDS
VINDYAN HIGH LANDS
SITE OF PROFILES
SITE OF POLICE STATION
SCALES
N
Suti
Lalgola
Bhagabangola
Sagardighi
Nabagram
Murshidabad
Berhampur
Domkol
Jalangi
Khargram
Hariharpara
Kandi
Barwan
Beldanga
Noada
Bharatpur
DRAWN BY
S.K.Haldar.
PREPARED BY
THE RAPID RECONNAISSANCE SOIL SURVEY
S.K.Mukerji, Agricultural Chemist,
West Bengal
1955.

LATERITE OF KUTCH

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The name laterite was originally suggested to a highly ferruginous deposit of an indurated clay, occurring in Malabar, South India, which is mostly used as building material. The term laterite was used in the geological literature of India and by explorers and geologists in many other countries. Laterites were reported on sedimentary materials, granites and basic rocks ; at elevations ranging from sea level to 8000 feet and under a climate of desert and semi-desert nature to high rainfall conditions. A typical profile usually consists of four successive zones or horizons *viz.*, iron stone crust or red ferruginous zone ; motted or iron stained clay ; white clay or pallid zone and then parent rock. Whitehouse (1940) recognised the occurrence of an additional horizon of a siliceous character in some profiles, the silicified material forming the basal horizon above the parent rock, frequently, however, occurring in the three other zones. The general uniformity displayed in the chemical and mineralogical composition of the laterites, whether developed from acid or basic rocks gave rise to much speculation by geologists and pedologists about the genesis of laterites and related soils.

Campbell (1917) distinguished the process of rock decomposition in tropics under two categories, alteration and weathering. Alteration takes place within the zone of permanent saturation and consists of elimination of much of silica, most of iron and some alumina and the conversion of alkaline silicates into hydrous silicates of alumina. True weathering takes place above the ground water level, while in the intermediate zone of fluctuating water table lateritization takes place. As Campbell (1917) puts it "Laterite is not derived from a rock, but is the result of gradual removal of the greater part of the mineral matter of the original rock and the gradual deposition in its place of lateritic constituents from passing solutions." These views seems to be shared by Prescott and Pendleton (1952). As the sketch map of laterite in India presented by Prescott and Pendleton (1952) appeared to be not comprehensive, some observations on the laterites of Kutch are presented here.

Laterite in Kutch. The jurassic rocks of Kutch, marked by the largest assemblage of red and ferruginous strata are overlaid in many places by trappean flows. At the end of the trappean period some volcanic flows of widely different aspect from the rest supervened. The most volcanic looking beds have often a derivative appearance but the manner of their occurrence is that of normal amorphous ash, perhaps subaqueous lava or possibly volcanic mud, that is to say the whole body, if it is chemical metamorp iosis, is altered (Wynne, 1892). Associated with these rocks are the laterites sometimes forming the basal and sometimes the uppermost bed, while ferruginous bands of very lateritic aspect appear in the tertiary series at some distance above the whole group. As described by Wynne (1892) "the laterites are earthy, compact or nodular and scoriaceous looking, sometimes so highly ferruginous as to become an iron ore." Detached representatives of the subnummilitic group, with its constant laterites, gypsum shales and white earthy rock occur in Eastern Kutch. Agates are usually embedded in the ferruginous lateritic rocks.

Description of Laterite profile. The hillocks in Wagud tract of Eastern Kutch are devoid of soil cover and vegetation exposing an iron crust.

A typical section of the profile examined near Adesar, Eastern Kutch showed one to two feet deep hard, highly ferruginous laterite crust, followed by a zone of white earthy rock with thin yellowish brown and reddish brown bands of iron oxides which gradually disappear with depth. This zone of about four to five feet extends into a pallid zone of white clay of great depth. The underlying rock is not seen in the cuttings examined but according to Wynne (1892) they are jurassic formations. A close examination of the laterite crust showed weak laminations and the interior of the rock, when split, showed mainly hematite and traces of weathered feldspar.

Results and Discussion

The data on chemical analysis of laterite and white clay is given in table I and the mechanical composition of the white clay in table II. The white clay showed a pH value of 8·3, 0·05 per cent. soluble salts, cation exchange capacity of 6 m.e. per 100 gms. and 37·6 per cent. water holding capacity. The laterite crust contains next to quartz a high amount of iron and lesser amounts of soluble silica and alumina. The white clay on the other hand contains considerable amounts of soluble silica and alumina and less than 2 per cent. of iron. Both the samples contain traces of titanium, manganese, calcium mangnesium and potassium which are included under the item "undetermined" in table I. A recalculation of the results on the assumption that all the alumina is present as Kaolin showed that the soluble silica as determined balances the alumina. It is likely that all the iron is not present as ferric oxide and the balance of water (cf. table I) exists in the hydrated forms of iron oxides. The low cation exchange capacity of the white clay is in keeping with the calculated Kaolin value. Possibly the sand is present as quartz while the silt and clay nearly correspond to the Kaolin content. It appears that in the laterite in addition to iron there is also an accumulation of silica as observed by Whitehouse (1940).

TABLE I

Chemical Analysis

	Laterite crust.	White
Loss on ignition	5·93	9·29
Quartz	48·20	38·20
Soluble silica	9·07	26·70
H. F. residue	0·60	0·19
Iron (Fe_2O_3)	27·20	1·90
Alumina (Al_2O_3)	7·62	22·70
Undetermined	1·38	1·02
	100·00	100·00
Kaolin	19·4	57·3
Quartz	50·2	39·4
Fe_2O_3	27·2	1·9
H_2O	3·2	1·4
	100·0	100·0

TABLE II

Mechanical Analysis

	Particle size in m. m.	Amount present	Particle size in m. m.	Amount present.
Clay	$<\cdot 002$	29·0	$<\cdot 005$	37·0
Silt	0·02 to 0·002	22·4	0·05 to 0·005	30·0
Fine sand	0·2 to 0·02	48·0	2 to·05	33·0
Coarse sand	2 to 0·2	0·6		

The laterites of Kutch are similar in their morphology and chemical properties to such formations reported elsewhere and may be regarded as fossil material. Green (1947) discounts the theories on the accumulation of sesquioxides (laterite) as due to upward leading of solutions. In Southern Sudan. Green (1950) reported contemporaneous formation of laterite material occurs not in plateau but in valley sites where subsoil water table is fluctuating and change occurs after a fall in the water table and not due to ascent of some laterising solution. In the flood plains of Rann of Kutch water stands 4 to 5 feet high in the monsoon months and sinks 5 to 6 feet or more below the ground level in dry period. In some profiles examined in this salty barren tract, Satyanarayana (1951) reported with top or surface gley horizon the lower layers are conspicuously stained with iron oxide in vertical streaks and channels and a zone of incipient iron pan formation above the gley horizon when it is at some depth. Satyanarayana and Datta (1953) observed intense activity of sulphate reducing organisms in deep gley horizons, negligible activity in top gley horizons and an inconsistent activity in the iron accumulation layers. Gleying is a phenomena observed in wet soils and some of the processes taking place under such conditions may be comparable to the laterite process of the past but we have not sufficient knowledge at present.

From the several publications it is clear, however, that the accumulated laterite constituents may be (*a*) predominantly iron (*b*) iron and alumina and (*c*) bauxite, with an occasional resilication or accumulation of silica in some of the horizons or zones. The solution or precipitation of silica and alumina are governed by the prevailing pH, while in the case of iron the processes are regulated by the pH and oxidation-reduction potentials. In these reactions the possibility of some of the bacteria, like sulphate-reducers and iron bacteria, playing an important role is not ruled out. The occurrence of laterite horizons in soils and pedogenesis over laterite crusts may be indicative of processes in time under changed conditions. A great deal of the theory of soil formation is still largely a guess work, inadequately supported by experimental data. (Alex Muir, 1947). It is most likely that the processes responsible for the formation of laterite horizons in the past are at work in the present also but since the several steps involved are not clear a confusion of ideas on their genesis is persistant.

SUMMARY

Laterites are reported in the tertiary formations of Kutch. They are morphologically similar to such formations in other places. The laterite crust is ferruginous and the pallid zone contains kaolin and quartz. Possibly processes analogus to those operating in present day wet soils with gley horizons were responsible for the formation of laterites in the past. The genesis laterites may become clear when the several steps in the process are established experimentally.

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SOIL FORMATION UNDER FOREST COVER

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While dealing with the natural soils of Saugar opportunity was taken to study the exact physicochemical role of tree litter in the development of soil. The site selected for the study was Patharia forest near the University of Saugar. The forest has been described by Misra and Joshi (1952) as monsoon decidous type with regional dominance of different species which deposit appreciable amount of litter in the spring season. The object of this paper is to assess the pedological behaviour of the substratum following the decomposition of the annual deposit of the litter as derived individually from ten common species of the forest.

The terrain consists of undulating plateaux and wide valleys built of the northern limit of the Deccan trap. The successive lava flows gave rise to the basalt with lime rich intertrappean beds. The soils arising out of this parent material are the red coloured soils of the plateaux tops and the black 'regur' soils of terraces and valleys. The red colour of the soil at the summits of hillocks is due to excessive leaching of monovalent and divalent bases and silica leaving behind a mixture of hydrated oxides of iron and aluminium imparting the characteristic colour. The intensity of silica loss and sesquioxides accumulation is remarkable in tropical weathering of traps. Pot-culture experiments were set up in the botanical garden as follows:

Red soil collected from the top of the hillock was thoroughly mixed and kept in twelve wooden boxes (10″ X 8″ X 8″) in March, 1953. The soils in ten boxes were covered with 75 gms. each of the litter of *Anogeissus latifolia, Tectona grandis, Terminalia tomentosa, Aegle marmelos, Lagerstroemia parviflora, Anona squamosa, Saccopetalum tomentosum, Maduca latifolia, Diospyros melanoxylon* and *Butea monosperma* respectively and the eleventh box had a mixture of all these and the twelfth was left as control. Decomposition of the litter was recorded monthly by estimating the fall in carbon-nitrogen ratio, change in pH and evolution of carbon dioxide. Litter analysis of all these plants is given in table I.

TABLE I

LITTER ANALYSIS

Species	Ash content %	Silica %	Sesq. %	CaO %	MgO %	K_2O %	P_2O_5 %
Aegle marm ...	16·54	13·46	0·10	1·792	0·17	0·384	0·174
Anogeissus lat. ...	11·84	7·62	0·95	2·226	0·43	0·348	0·156
Anona squam. ...	8·42	5·24	0·70	1·708	0·10	0·320	0·156
Sac. tomentosum ...	8·78	6·23	0·35	1·582	0·28	0·360	0·219
Dio. melanoxy. ...	4·86	2·58	1·10	1·316	0·10	0·160	0·117
T. tomentosa ...	12·62	9·20	0·40	1·904	0·23	0·288	0·108
Tectona grand. ...	24·60	20·64	0·30	2·860	0·34	0·480	0·090
Lagerst. parvifl. ...	5·48	2·44	0·90	1·162	0·12	0·276	0·228
Butea monosp. ...	13·40	8·84	1·05	3·010	4·47	0·504	0·132
Maduca lat. ...	7·68	4·76	1·25	1·701	0·21	0·304	0·216

The soil was analysed for its various properties in November, 1954 after the litter had disappeared. Methods of analysis as given by Piper (1952) and A. O. A. C. (1952) have been followed. The results in general give the following sequence of rapidity in decomposition as found for the ten species :—*Aegle marmelos*, *Anogeissus latifolia*, *Anona squamosa*, *Saccopetalum tomentosum*, *Diospyros melanoxylon*, *Terminalia tomentosa*, *Tectona grandis*, *Lagerstroemia parviflora*, *Butea monosperma* and *Maduca latifolia*.

We know that all plant formations whether big or small do exert certain influence on the various properties of soil but all these formations do not become a soil forming factor. It is only that aspect of vegetation a 'Soil forming factor' which can affect the property independently *i.e.*, the changes produced may not be correlated to any other factor of soil formation. To achieve this end, therefore, all other factors of soil formation were kept constant in the pot culture experiments to correlate the various properties of the soil with the nature of litter.

Changes in Various Physical Properties of the Soil

Soil water relations.—From the ecological point of view the two critical quantities are capillary water which upon reaching its maximum determines the field capacity and non-capillary water which gets drained under the influence of gravity. During the present course of investigation it has been found that capillary water, gravitational water, moisture content and water-holding capacity increase with the addition of organic matter. (Table II). Not only different types of soil water are improved but their relative quantities are determined by the rate of decomposition of various plant litters.

TABLE II

Organic Matter and Soil Water Relation

Species	Loss on ignition %	Moisture content %	Field cap %	Water holding cap
Aegle marmelos	8·624	1·854	26·90	42·02
Anogeissus lat.	9·146	2·157	27·71	42·11
Anona squamosa	9·493	2·470	27·74	45·37
Saccopetalum tom.	9·493	2·226	27·80	45·82
Dio. melanoxylon	9·504	2·293	28·13	45·86
Term. tomentosa	9·734	2·327	30·65	46·00
Tectona grandis	10·230	2·547	30·66	47·30
Lager. parviflora	10·520	2·591	30·70	47·12
Butea monosper.	10·982	2·565	30·64	50·08
Maduca latifolia	11·884	3·016	30·87	52·10
Mixed	9·786	1·934	28·80	48·13
Control	6·112	1·652	22·41	41·01

Pore volume.—Weight-volume ratio decreases with the addition of organic matter. Thus organic matter helps in opening up compact soils. Pore space may either be capillary or non-capillary, former being important in water holding capacity and the latter in determining air capacity which controls internal drainage of water. Nature of pore space, therefore, is very important because it determines soil water and soil air and both of them are improved by the addition of organic matter. It has been observed that the increase in pore volume is not due to the field

capacity in practically all cases, this has been on the other hand markedly influenced by air capacity. Non-capillary pore space, therefore, significantly increases with addition of organic matter.

TABLE III

SOIL AERATION IN RELATION TO ORGANIC MATTER

Species		Loss on ignition %	Wt./Vol. ratio	Air capacity %	Percentage pore-vol.
Aegle marmelos	...	8·624	1·20	27·50	54·40
Anogeissus lat.	...	9·146	0·86	39·61	67·32
Anona squamosa	...	9·493	0·96	35·76	63·50
Sacc. tomentosum	...	9·493	1·40	19·00	46·80
Dio. melanoxylon	...	9·504	1·10	32·20	62·30
Term. tomentosa	...	9·734	0·80	38·65	69·30
Tectona grandis	...	10·230	1·50	17·34	48·00
Lag. parviflora	...	10·520	0·87	37·24	67·94
Butea monosp.	...	10·982	1·50	8·36	39·00
Maduca lat	...	11·884	1·00	31·13	62·00
Mixed	...	9·786	1·25	25·00	53·80
Control	...	6·112	1·81	9·20	31·60

Soil structure.—Soil structure which is a function of aggregation depends on two factors namely clay fraction and cementing material. During the present investigation it has been found that organic matter increases both clay fraction and granulation (Table IV).

TABLE IV

SOIL STRUCTURE IN RELATION TO ORGANIC MATTER

Species		Loss on ignition %	Humus %	Clay fractions %	Aggregates %
Aegle marmelos	...	8·624	0·612	10·240	16·88
Anogeissus lat.	...	9·146	0·636	10·750	18·57
Anona squamosa	...	9·493	0·680	11·365	19·00
Saccopetalum tom.	...	9·493	0·468	12·590	24·11
Dio. melanoxylon	...	9·504	0·994	13·225	24·28
Term. tomentosa	...	9·734	0·896	13·335	24·32
Tectona grandis	...	10·230	0·808	13·400	28·98
Larg. parviflora	...	10·520	0·874	13·790	30·86
Butea monosperma	...	10·982	1·052	14·354	31·53
Maduca latifolia	...	11·884	1·188	14·396	32·02
Mixed	...	9·786	0·904	14·120	23·99
Control	...	6·112	0·586	7·850	12·78

These observations are in line with those of Warming (1909) and Baver (1940). However, subsequent workers like Metzger and Hide (1938), Stauffer and his co-workers (1940), Li and his co-workers (1942), Browing and Milam (1944), McHenry and Newell (1947), Ackerman and Myers (1943) and Rost and Rowles (1941) have found no relation between organic matter and aggregation because the soil reverts back to its original structure after the removal of organic matter by ch mical oxidation or biological decomposition. It has been found in the aggregate analysis of litter treated soils that silt and clay fractions are considerably reduced

and the amount of fine sand increases proportionately. There is no change whatsoever in coarse sand size. It is, therefore, concluded that silt and clay fractions aggregate to form compound particles of fine sand size. Aggregation increases as the rate of decomposition decreases. Thus it is maximum in *Maduca latifolia* and minimum in *Aegle marmelos* and others vary between these two extremes.

Changes in Chemical Properties

Contrary to the general understanding, that the leaf falls, decomposes and the minerals therein are added to the soil, it has been found that the minerals are removed from the soil as a result of addition of organic matter (Table V).

TABLE V

Effect of Litter on the Mineral of Soil

Species		Field cap	Loss on ignition	Silica	Sesquioxides	CaO	MgO	K_2O	P_2O_5
Aegle marm.	...	26·90	5·24	51·96	7·80	0·868	0·440	0·58	0·011
Anogeissus lat.	...	27·71	6·70	52·63	8·09	1·028	0·973	0·63	0·027
Anona squa.	...	27·74	6·10	52·64	8·58	0·742	0·380	0·63	0·012
Sac. tomentos	...	27·80	6·84	50·74	8·47	0·994	0·450	0·56	0·022
Dio. melanoxylon	...	28·13	6·30	52·25	8·49	0·721	0·370	0·61	0·070
T. tomentosa	...	30·95	5·30	50·22	9·38	0·693	0·362	0·53	0·016
Tectona grand	...	25·66	7·40	51·56	9·78	0·889	0·730	0·60	0·019
Lagerst parvi.	...	30·70	7·60	51·76	7·41	0·910	0·460	0·41	0·068
Butea monosp.	...	26·64	5·60	50·77	8·04	0·756	0·350	0·52	0·030
Maduca lat.	...	30·87	7·56	50·13	7·04	0·767	0·290	0·65	0·048
Mixed	...	28·80	6·02	51·95	8·96	0·742	0·380	0·54	0·029
Control	...	22·41	4·92	53·95	10·45	1·280	0·880	0·84	0·082

This anomaly can be explained when the leaching is considered in the light of plant cover. Soil, without any cover becomes impermeable due to the hammering of rain drops which let loose the colloidal particles into suspension closing thereby the pores with the result that infiltration ceases and leaching down of minerals and soluble salts is avoided. The reverse is true with litter treated soils. Due to protective action of organic matter, the pores remain open and thus internal drainage is facilitated which helps in removing the soluble salts. When the leachate from the control and litter treated soils were analysed for sesquioxides, calcium, potassium, etc., only calcium was found to be present in appreciable quantity. While the amount of calcium (per unit volume) leached out from the control was double of that of the treated pots the net leaching of calcium from the latter was appreciably higher : this is due to the greater intensity of leaching and subsequent removal by downward percolation facilitated by the addition of organic matter. This fact would explain the decrease in the mineral content of the pots after addition of organic matter. It is clear from the above table that silica and sesquioxides are washed away from the litter treated soils. Under tropical conditions the high temperature causes a rapid mineralisation of organic residues and increases the solubility of alkali and alkaline earth metals which are leached out by percolating water along with silica and a more or less neutral medium results which helps the accumulation of iron and aluminium oxides because of their insolubility at neutral reaction. The hydroxides of iron and aluminium are

capable of existing in collodial condition which are very sensitive to electrolytes. In the absence of lime, as in the present case, and in the presence of water, humus tends to pass into a collodial solution which unlike the sols. of iron and aluminium is not very sensitive to electrolytes. In a solution, therefore, which contains humus sol. and iron and aluminium sol., the former protects the latter rendering them less liable to precipitation. Thus in soils with free drainages like all those treated with litter, percolating water carries away iron and aluminium hydroxides. Secondly different organic acids produced during the decomposition of various litters have a remarkable solvent action on iron and aluminium. Iron and aluminium dissolved in organic solvents cannot be precipitated by ammonia probably due to formation of a complex radical and that is why inspite of their presence no precipitate for iron and aluminium was found in the leachate from the experimental pots.

Exchangeable bases.—Exchangeable metallic cations and base saturation decrease and exchangeable hydrogen and exchange capacity increase as a result of litter treatment (Table VI).

TABLE VI

EFFECT OF ORGANIC MATTER ON EXCH. BASES

Species	Loss on ignition %	pH	Exch. metal cations m. l.	Exch. Hydr. m. l.	Total exch m. l.	% base saturation
Aegle marm.	8·624	7·09	56·4	28	84·4	66·8
Anogeissus lat.	9·146	6·69	52·4	27	79·4	67·7
Anona squam.	9·493	7·20	52·5	31	83·4	62·8
Sac. toment.	9·493	7·37	52·5	35	87·5	60·0
Dio. melanox.	9·504	7·20	54·5	32	86·8	62·7
T. tomentosa	9·734	6·73	52·5	15	67·5	77·7
Tectona gr.	10·230	6·65	52·5	16	68·5	76·6
Lagers. parv.	10·520	7·07	56·4	11	67·4	83·6
Butea mono.	10·982	7·10	50·5	15	65·5	77·7
Maduca lat.	11·884	7·34	58·5	12	70·5	82·9
Mixed	9·786	7·36	54·4	12	66·5	81·3
Control	6·112	7·40	64·4	2	66·4	96·9

Amount of exchangeable hydrogen depends on the nature of organic matter and increases with the rate of decomposition. Thus *Saccopetalum tomentosum* and *Anona squamosa*, least resistant, have the maximum value and *Maduca latifolia* and *Lagerstroemia parviflora*, most resistant, have the minimum value for exchangeable hydrogen. It is seen from the Table VI that high acidity is not caused by exchangeable hydrogen otherwise maximum acidity would have been in *Saccopetalum tomentosum* or *Anona squamosa* but it is more likely that high acidity results from the soluble salts of iron and aluminium.

$$Fe\,Cl_3 + 3H_2O\ Fe\,(OH)_3 + 3HCl$$

SUMMARY

1. The effect of ten forest tree litters on the various physical and chemical properties of the soil have been studied.

2. Moisture content, organic matter, water holding capacity and field capacity increase with the organic matter.

3. Soil structure, physical texture and aggregation are improved.

4. Pore volume and air capacity increases when the soil is treated with organic matter.

5. Organic matter, in different stages of decay, accumulates in varying quantities.

6. The downward movement of soluble materials by percolating water results into gradual impoverishment of the surface soil.

7. Cation exchange capacity increases with organic matter.

8. Colloidal particles attain high hydrogen ion content and correspondingly low contant of metal cations.

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SECTION—9

SOIL CONSERVATION AND MANAGEMENT

PLANNING FOR SOIL CONSERVATION IN THE DAMODAR VALLEY

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(Received on 9th October, 1954)

Soil conservation aims at better land use. The best use of land is one in which land produces the maximum and deteriorates the least.

The upper Damodar catchment has an area of nearly 4·4 million acres, out of which 1 million acres is forest, 0·8 million acres paddy, 0·8 million acres forest, 0·8 million acres upland, 1·0 million acres wastelands and remaining 0·8 million acres is under settlements, roads, etc.

The southern half of the upper Damodar catchment is drained by Damodar and its tributaries. The northern half is being drained by Barakar river and its tributaries. The Barakar catchment and in particular the sub-catchments of Usri and Irga are the worst eroded areas of the valley. The present state of catchment is conducive to high runoff coefficient. The amount of rainfall of upper Damodar catchment averages about 46·5," with a maximum of 64·3" and a minimum of 30·6".

Soil conservation planning has two main objectives. The first is to maintain soil productivity by practial measures for conservation of soil and water. The second is land use adjustments in headwater areas to protect and further the effectiveness of downstream engineering works, of retarding runoff and decreasing rate of silation.

Method of approach in planning.— Soil conservation planning in the upper Damodar Valley has been taken up within each catchment boundaries, since soil erosion is essentially a phenomenon of a catchment unit. The whole of upper catchment has been divided into a number of sub-catchments for the purpose of planning and execution of soil conservation measures. The catchment is a body of land bounded on the upper side by a ridge or water divide and at the lower and by the level at which water drains out. In each small catchment soil conservation surveys are being conducted on the uplands, wastelands denuded forests and gullied lands to obtain the basic data of soils (soil depth, texture, permeability, external drainage pattern, etc.), erosion and present land use, to prepare land capability map delineating land capability classes, suggesting recommendations for erosion control on such lands by putting the lands to the use to which it is best suited and recommending measures it needs to bring it into productive condition. It is proposed to prepare working plans for each small catchment after a study of land capability classes.

Preparation of working plan for soil conservation for a catchment.—In the preparation of a working plan the following points are given due consideration :

(1) Plan as far as possible, must apply complete treatment for using and treating the land and be simple to be followed by farmers,

(2) The problem of soil conservation has to be tackled both on cultivated as well as wastelands in each catchment,

(3) Planning must be based on land capabilities with due consideration of socio-economic conditions of the area,

(4) Planning for water conservation is of utmost importance in the valley,

(5) Soil and water losses are a direct result of rainfall and hence soil conservation planning must be based on hydrographic units. For designing erosion control structures with proper capacity, critical runoff is calculated.

A working plan constitutes some of the following soil and water conservation measures depending on the nature of catchment:

(1) Proper management of existing forests and afforestation to rehabilitate waste and eroded areas,

(2) Reclamation of uplands, wastelands for paddy, upland cultivation, pasture or forests according to land capability,

(3) Terracing of uplands with low, broad graded channel terraces with stabilized outlets, following soil conservation, crop rotations and contour tillage with adequate fertilization and green manuring, discouraging up and down cultivation,

(4) Fertilization and irrigation facilities for paddy fields,

(5) Fodder production in Kharif and Rabi to reduce excessive grazing and encouraging stall feeding,

(6) Controlling gullies by some of the following treatments, depending on location, dimensions and various other factors :

(*a*) Protection from grazing,

(*b*) Head sloping of most active gullies and establishing grass by sodding and seeding,

(*c*) Where upland fields drain into gullies, collect the drainage water in broad shallow sodded channels (diversion channel) which run parallel with gullies and discharge this water into gullies at interval through sod and stone flumes,

(*d*) Check Dams,

(*e*) Conversion of some gullies into paddy fields or afforestation according to suitability.

Suggested approach for execution of working plan.—To achieve the recommendations implemented on all the uplands, wastelands, gullied lands within a catchment which belongs to different cultivators of the same village or of different villages, it is essential that approach be made to persuade villagers (may be through Panchyat to coerce the unwilling minority into doing what they are told to do)

having lands with common problems to accept the measures. In a way, plan for each farmer's land separately is not possible for holdings are scattered. In the absence of regular consolidation of holdings, the best way to get this programme of soil conservation started is by giving demonstrations of soil conservation measures to the villagers on their lands, and a voluntary consolidation of holdings and joint management of the measures like terrace, etc. made on such lands is necessary. It is to be stressed that by far the greatest amount of soil conservation must be done by the farmer himself on his land with his equipment or equipments within his means. Farmers must participate in the programme. Soil Conservation Department of the Damodar Valley Corporation have started the work with 50% contribution of the Damodar Valley Corporation, in the shape of seeds, fertilizers, equipments, etc. and remaining 50% or even less sometimes from farmers in the form of labour or material. If farmers are willing to contribute all the labour, then a proportionate amount saved from this is diverted to give them seeds and fertilizers, etc. In the initial stages any state will have to spend more for such works, and once the programme gets started, it will be taken up by farmers themselves.

For final execution of recommendations, a detailed contour survey of blocks of lands already soil surveyed and needing protection, is undertaken which will determine the specifications for terracing (vertical internal, grade of channel, etc.), gully control structures and water disposal system as influenced by rainfall intensity and critical runoff.

A REVIEW OF SOIL EROSION AND ITS CONTROL IN NEW SOUTH WALES (AUSTRALIA)

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(Communicated by Dr. S. P Mitra)

Soil erosion is a great menace to any country, and particularly so in the case of a country which has to depend on Agriculture for its national economy and a better standard of living. It is the primary need of such a country to maintain the surface soil rich in nutrients and possessing fine structure. Probably every country in the World is subject to erosion whether more or less severe and New South Wales is no exception to this. The climate and soil conditions are such that the soils get torn off at a very rapid rate. This is further helped by the unwise, intensive as well as extensive use of the land. These factors have taken such a big toll of the land that nearly half of the total area in central and eastern divisions of the state have suffered through moderate or severe erosion.

Erosion Survey of the above mentioned areas revealed that 38 % of the area under the two divisions has been severely affected. Over a million acres covering an area of about 1856 square miles have been found to be beyond repair. This area was in the initial stages very productive, but as mentioned earlier, due to faulty practices of cultivation the land has now become unproductive. A further area of 85,700 square miles constituting about 55 million acres have undergone moderate erosion. This gives a fair idea of the magnitude of the soil erosion that has already taken place and the gravity of the situation.

*The article is based on the information and data collected by the author during a two months study tour to Australia under the Colombo Plan.

Water and wind erosion are the most important types. Water erosion is in severe form on undulating and cultivated lands, particularly so in the wheat belt and on steep lands which are normally overgrazed. Wind erosion takes the shape of scalds or shifting dunes and is very common in the area where the rainfall hardly ly exceeds 15-18 inches and on the pasture lands which are overgrazed. Orchards and other crops taken on steep hills in the high rainfall areas are also very susceptible to erosion which takes the form of gully and sheet erosion. It is proposed to discuss here only the erosion due to rain.

Soil erosion research conducted at different stations in New South Wales reveal very interesting figures. The Wellington Research Station which is in the midst of the farm lands started its work on practically highly eroded land. The account of soil and water lost from the wheat cropped areas during the period of preparation of land and the harvest of the wheat crop is on an average of 9,470 lbs. of soil per acre and 13·6 % of the rainfall respectively. At Cowra soil and water erosion has been studied under different treatments on well laid out plots each having an area of 1/40 acre and measuring approximately 8 × 136 ft. The following table gives the figures for mean annual runoff and soil loss during the period of seven years of experiment :

TABLE I

Treatment	Wheat fallow.	Wheat ley fallow	Lucerne	Sown pasture	Land retired from cultivation
Soil loss in lbs. per acre	3,733	1,388	1,197	1,058	688
Runoff in inches per acre	1·27	0·89	1·37	1·28	0·81

Further it has been observed at this station that "with the increase in the length of plot there is a proportionate decrease in the runoff but the smaller run moves proportionately more soil."

At Wagga-Wagga the average runoff caused by five rains reveal that 81 % comes out of wheat stubble plots, 42 % out of fallow plots and 25 % out of pasture plots. The soil loss over the same period from these plots is 1,619, 4,089 and 196 lbs. per acre respectively.

These findings came very handy when the methods of soil conservation were chalked out. In the beginning there was a belief that soil erosion can be controlled only by mechanical means such as using big earth moving machinery which means high cost of equipment, etc. It is true that mechanical means are a necessity where the lands have been so eroded that the parent material or rock is exposed and other normal methods are useless. But it was realised that to think in terms of only mechanical means would be a folly. Measures were therefore adopted for treating the different stages of erosion with different methods of control.

It is well known that the best method of protection for the land against erosion is to have appropriately selected vegetation. In cases of very serious erosion it is primarily important to control runoff before vegetation can be intro-

duced and therefore it may be needed first to subject the area to mechanical means of control such as laying out contour furrows, contour and graded banks, water ways, diversion banks, etc. The mechanical devises laid out will no doubt be dependent upon a number of factors such as soil type, slope, climate, and the stage of erosion. The agronomic way of prevention of soil erosion is to put the land to proper use by pasture improvement, crop rotation, contour cultivation, etc. Thus it can be seen that the soil conservation problem can be effectively tackled in two ways, namely by mechanical means and by correct agronomic practices. The mechanical control methods help to increase the time which the surface water will take for the flow from the area . This will mean increase in the concentration of the moisture in the soil which in turn will decrease the runoff.

The mechanical method as mentioned earlier consist of laying out contour furrows, contour and graded banks, diversion banks, etc. Out of these the most economic and effective seems to be the laying out contour pasture furrow. These pasture furrows have the effect on controlling the runoff and pasture seeds are normally caught in the furrows instead of being wasted or blown away and in view of the sufficient moisture in the soil, thick pasture grows rapidly. These are usually used on grazing lands having high slope. These pasture furrows indirectly help to improve the quantity and quality of the grasses. In laying down these contour furrows a road plough is used. Sometimes even a reversible type of disc plough is used.

Contour banks are normally taken up on slopy cultivated lands and are mostly graded and broad based. The lengths are normally less than 1,500 ft. and very rarely the grades exceed 0·5 % at the furthermost points. These have been found to be very effective in controlling erosion and runoff even in the black soils. It is of utmost importance that immense care has to be taken in the first two years of their construction as very heavy rains during this period might cause breaches. Normally these are protected by diversion banks and grassed waterways, the latter being most essential step prior to laying out contour, graded or diversion banks. These banks are either laid out by using grader or dozer or disc plough as the case may be.

Holding dams are mainly constructed for preventing erosion by control of run-off flow to the low lying areas. These are further used as water supply for the stock as well as domestic purposes. These can be constructed by using dozers or scoops.

Coming to the agronomic practices in the control of erosion and run off, the first important point to be borne in mind is the proper land use. Much attention is paid to bring the land under cultivation to best suited crops. Intensive cultivation is limited to flat areas and areas having gentle slopes. The steep areas are put to pasture only when these are protected by contour or graded banks. Further inferior areas are normally not cleared at all.

The next step taken is to see that the cultural operations and sowing are done in contour. When the pasture is sufficiently grown, the area is grazed very judiciously avoiding over stocking. This helps in keeping the required cover on land in times of rain. This is conveniently done by adopting rotational grazing and avoiding large stocks. Care is also taken to see that these areas are not infested by rabbits which do a lot of damage in the absence of proper control. Further, close attention is given to improve the pasture in such a way that greater and greater protection is afforded to the land and the infiltration of the water is increased thus considerably reducing the threat of soil and water losses.

Another important measure adopted in controlling the soil and water loss is the practice of rotating the crop. It has been noticed that one crop farming has been the main cause in many cases of erosion in cultivated areas. Even fallowing as a sort of rotation does not help in any way, on the contrary it keeps the soil at the mercy of the rain and wind. As such the rotation of suitable crop is adopted. Either grass or a suitable legume is normally rotated with crop or sometimes straw is allowed to remain on the ground. This method of rotation of erosion resisting with the erosion permitting has helped a great deal in controlling the erosion.

By adopting suitable combination of mechanical and agronomic control the country has made a great headway in controlling soil and water conservation. The areas brought under such measures have been vastly improved in soil fertility and crop production. In our country there are good many areas where such conditions like steep slopes, highly erodible soils and torrential and erratic rains occur and, therefore, if some of these methods, if not already undertaken, can be effectively used with certain modifications wherever necessary. The probable difficulty with us will be the presence of small holdings of our farmers but these methods may be useful to the areas where now community projects or co-operative farming centres are working.

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REVIEW OF SOIL CONSERVATION IN THE GISBORNE EAST COAST REGIONS OF NEW ZEALAND

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INTRODUCTION

The Gisborne-East Coast region lies in the north-east corner of the North Island of New Zealand between latitude 37 degrees South and 39 degrees South (Fig. 1). It is bounded on the north and east by the Pacific Ocean and on the west by the axial, Raukumara range and in the south by high hills commonly known as the Wharerata hills. In this paper, the region includes the counties of Matakaoa, Waiapu, Uawa, Waikohu and Cook, which together cover an area of 3,200 square miles.[1] Gisborne, with a population of almost 20,000 is the principal town and port.

The region is renowned for its spectacular forms of erosion.

TOPOGRAPHY

The crust is deeply and finely etched to give a pattern of narrow valleys, steep hills and sharp ridges. The land starts precipitously at the coast with summit levels of about 1,000 feet above mean sea level, rises quickly to a general level of about 2,000 feet and culminates at the Raukumara range some 4,000 feet above mean sea level. Towards the northern end of the range are a number of conspicuous rugged peaks, the highest of which Hikurangi, stands above 5,600 feet.[2] There are two drainage systems each of about the same area and with an east-west divide, and the courses of the main rivers trend north and south respectively in each system.

For land use, the land-slope is rather important. The table below gives the range and proportions of land slopes based on topographical units which have been found by the New Zealand Soil Bureau[3] to be significant in modifying both the soil and land use.

TOPOGRAPHICAL UNIT		Proportion as %
Flat		6
Easy Rolling	Most slopes under 5 degrees.	7
Rolling	Most slopes under 12 degrees, many slopes between 5 and 12 degrees.	5
Moderately Steep	Most slopes under 30 degrees, many slopes between 12 and 30 degrees.	24
Steep	Many slopes over 30 degrees	58

It is thus clearly apparent, that by far, the dominant land-slopes are steep and moderately steep. In comparison, the area of flat land is only 127,000 acres.

Climate

The climate is mild and humid. The distribution of the rainfall follows closely upon the elevation of the land. For instance, on the Raukumara range, the annual precipitation is over 100 inches (175 raindays) and on the high hills flanking the range and on the drainage divide and on the Wharerata hills in the south, the rainfall range is 60 to 100 inches per annum (150 raindays). There is a drier pocket on the catchments of the southern drainage system leading into the Gisborne Plain where the annual precipitation is 40 to 60 inches (100 to 125 raindays).[4] At Gisborne, which is at sea level, the mean minimum winter temperature is 41 degrees F. and the mean maximum summer temperature is 78 degrees F.[5]

According to Garnier[6] the climatic types after Thornthwaite's classification, range from Superhuman (AC'r) for the Raukumara range, Superhumid (AB'r) for the high hills and Humid (BB'r) for the lower hills near Gisborne.

Occasions which cause most anxiety for soil erosion and flooding are when depressions track north of New Zealand. Here, rains from either a northerly or easterly direction, lash the countryside and if all of the catchments making up to drainage system are simultaneously drenched, then a general flood in the lowlands can be expected. As much of the vegetative cover is in the nature of grass and as many of the soils are shallow and skeletal, there is a limited capacity for absorbing water. If the storm is prolonged, the soils soon lose strength and in consequence slips and slumps are common.

Vegetation

In pre-European times, the land was clothed in a dense cover of forest. There were mainly two tree associations, a beech one which grew on the higher terrain from 2,000 to 4,000 feet, and a broadleaf-podocarp one which flourished on the lower hills below 2,000 feet and at the boundary there was much interdigitation of one association with the other. In the beech association there was a range of species according to altitude, the mountain beech (*Nothofagus cliffortioides*) growing between 3,000 and 4,000 feet followed in descending order but in diffused zones by silver beech (*Nothofagus Menziesii*), red beech (*Nothofagus fusca*), hard beech (*Nothofagus truncata*) and black beech (*Nothofagus Solandri*), at about 2,000 feet. The latter commonly invaded the broadleaf-podocarp zone and the broadleaf, tawa (*Beilschmiedia tawa*) was often found high up in the red and the hard beech zones.

In the podocarp-broadleaf zone, the forest pattern was a mosaic based on site and aspect. On the dry, northerly spurs black beech, tawa, totara (*Podocarpus totara*) and tanekaha (*Phyllocladus trichomanoides*) flourished and on the wet southerly slopes the podocarps, rimu (*Dacrydium cupressinum*), miro (*Podocarpus ferrugineus*) and matai (*Podocarpus spicatus*) grew abundantly. On the wet floors of valleys and river flats, kahikatea (*Podocarpus dacrydioides*) was dominant and along the coast, karaka (*Corynocarpus laevigata*), ngaio (*Myoporum lactum*) and pohutukawa (*Metrosideros tomentosa*) were prominent.

On the lower hills of the Waipaoa River catchment, where the rainfall is lowest for the whole of the region, the cover at the time of European settlement was partly bracken fern (*Pteridium esculentum*) and partly manuka (*Leptospermum scoparium*)

The area occupied during 1952-53 is near 2,000,000 acres which is about one-tenth of the total area of the region and the area in grasses, clovers and lucerne is near 1,500,000 acres[7]*.

*Unfortunately the manner in which the tables are set out in the "Report on the Farm Production Statistics of New Zealand for the season 1952-53" does not allow of a precise figure being obtained.

All are agreed that the canopy of protective forest on steep hills breaks the impact of raindrops and that the litter on the forest floor absorbs the water and checks the run-off. The geologists, Henderson and Ongley[8] were so alarmed at the effects of deforestation on the hills in the Waipaoa River catchment during the year 1914-16 that they devoted a section to the subject in their bulletin and their remarks on erosion, run-off and floods could not be improved upon even today. They instance investigations that were made into the incidence of accelerated erosion even as far back as 1894.

There is no doubt that the dense cover of forest effectively masked the nature of the underlying rock[9] and gave no clue as to the potentiality of rock erosion.

No one denies that there was not erosion under a forest cover. It is commonly believed that the movements were of a large scale nature and there was then not the comminution of soil and rock as there is today. In fact the soils of the large depositional basin, the Gisborne Plain, show that there was a period in the not-long-distant past when little sedimentation occured.

GEOLOGY

The rocks are of Cretaceous and Tertiary age.[10] They are sediments of a geosyncline which was thrust up in the Pliocene and subsequent erosion has carved out the present youthful landscape. In structure, the Raukumara range is part of the eastern axis of the North Island and there is a gradual descent from the old rocks in this axis, south-east, through successively younger beds to the coast. The structural trend is truncated by the coast line from Mahia to East Cape.[10]

In the Pleistocence and continuing into the recent[10, 11] there was considerable volcanic activity in the centre of the North Island and the hills of the region were mantled by a succession of ash showers the last one being dropped in 250 A. D.[12] The mantle is not now well preserved for distinct ash beds are only identifiable in about 30% of the area, the rest of the mantle being eroded or washed away. Indeed, the mantle can be used as a yardstick to measure the incidence of erosion. Where identifiable, the ash is soil forming and even on steep slopes and in the absence of mantle, the ash does influence the texture of the soil by making an otherwise heavy soil from mudstone much sandier. Hill soils from ash are very liable to earth and soil slips after heavy and prolonged rain.

As geological erosion is extensive and deep, all of the geological formations or lithologic units are exposed somewhere in the region and indeed many of them are parent rocks of the soil. Even though the rocks are soft, Hamilton and Kelman[9] found that there is an order of erodibility among them and this has proved a useful device in the study of soil conservation problems.

The Raukumara range is constructed of indurated, well-banded sandstone and mudstone of Cretaceous age but the formations on the eastern flank, also of Cretaceous age, are black, much-sheared argillite in the north and soft, shattered blue argillite in the south notably in the headwaters of Waipaoa river. The latter seems to have some affinity for water and disintegrates readily under the action of the weather.[8] On these formations, the protective forest cover has long been removed, the soil skin is now punctured, and the debris from gully erosion is now an embarrassment to the lowlands. In the north, the rock detritus spews out in the form of fans, on the top of which, streams run willy-nilly as to endanger property and roads, while in the south, the rubble from 40 miles of gullies[9] in the crushed argillites is now forcing the Waipaoa river to aggrade in its upper reaches.

The lower Tertiary formations include bentonite and bentonitic mudstones which commonly follow long crush zones and the highly colloidal material from gully erosion of these mudsones forms much of the suspended load of rivers. The formations of the middle Tertiary, consisting of calcareous mudstones, massive mudstone, banded sandstone and mudstone and gritty sandstone are the most stable, even at steep slopes, and erosion problems on these can be related to the soil.

Formations in which rock erosion is spectacular may amount to about 24% of the area of the region and it is here that erosion can be regarded as a "geological" problem. However, 15% is still under forest.

SOILS

As much of the land is steep, many of the soils are necessarily of a skeletal character and from soil maps of the region, the aggregated area of such steepland soils is about 60%. For the most part of the skeletal soils are shallow, from 3 to 15 inches. Where the forest has been cleared, the top soil is often absent because of accelerated erosion and hence only those areas with fertile sub-soils have responded readily to farming.[3] The sub-soils vary widely in fertility according to the nature of the underlying rocks and one of the most fertile is mudstone and one of the least is sandstone. Mudstone has a predisposition to slip badly, but the slip scars soon heal whereas the scars from sandstone take a long time to heal over.

On the rolling and hilly lands, where the volcanic ash mantle is well preserved, are the Yellow Brown Pumice soils from the coarser pumice ashes and the Yellow Brown Loams from ashes of finer material.[12] After a heavy prolonged rain, earth and soil slips are common on hill soils.

It is clear that soil conservation measures should be designed to hold the skeletal soils in place.

FARMING

The principal land use is in livestock farming which is conducted on large holdings of from 500 to 15,000 acres.[7] The region is noted for the breeding of sheep and cattle and for the production of wool. Each year large numbers of surplus stock are sent out of the region either to be fattened on the low-lands or to be used as replacement stock for fat lamb production elsewhere.

The table below gives the stock population for the season 1952-53.[7]

County		Sheep	Beef Cattle
Matakaoa	...	100,783	
Waiapu	...	400,954	
Uawa	...	211,862	226,977*
Waikohu	...	581,025	
Cook	...	723,621	102,457
Total		2,018,245	329,434*

A recent study in production trends and potentials of livestock farming in the North Island by the New Zealand Department of Agriculture[13] shows that the carrying capacity is for the most part low, but as the area is extensive and carries over 2,000,000 sheep, this is a significant proportion of the North Island total.

*This figure includes the beef cattle population for the county of Opotiki, which, together with the other counties mentioned makes up the Gisborne Land District. Except for Cook County, the "Report on the Farm Production Statistics of New Zealand for the season 1952-53" does not give the beef cattle population figures for each county separately.

Since 1921, the area occupied has remained virtually unchanged at nearly 2 million acres and the area in sown grasses is also almost static with a slightly declining tendency. There has been a decline in the number of breeding ewes and total sheep since 1941, but to compensate for this, there has been an increase in beef breeding cattle. This feature, the Department regards as a healthy sign as it considers that much of the land has been over stocked with sheep and that insufficient use of cattle has been made for improvement of pastures.

A conclusion from the study is that the carrying capacity can be raised partly by correct and balanced stocking and partly by improvement of the pastures now that the application of artificial fertilers by aircraft is quite practical ; but that by the nature of the country there are serious economic and technical problems to be overcome. One of these is accelerated soil and rock erosion.

As an indication of the productivity of the region, the value of the 1953-54 wool clip is estimated (the precise figure is not easily accessible) at near New Zealand £ 4,000,000.

Soil Erosion Surveys

In 1948, Grange and Gibbs[14] published an account of soil erosion in the southern half of the North Island, which includes all of the Gisborne-East Coast region. They classified slip erosion on steep and hilly slopes principally on the hardness or softness of the rock exposed and whether erosion of the rock followed upon exposure. The type of exposed rock and the ease of establishment of vegetation upon it were also incorporated in the classification. To give a picture of what is happening to the land, the classes of erosion were grouped into three categories, which are modified and presented in the table below.

Land	Proportion of the region as %
Land in which there is no significant deterioration ...	19
Land in which there is slow deterioration ...	46
Land in which there is rapid deterioration ...	35

In 1952, Hamilton and Kelman[9] conducted a soil conservation survey of the Waipaoa River catchment. The Waipaoa River is the principal river in the southern drainage system and the area of the catchment is some 540,000 acres of which 87% is in grass.[9] They produced a land inventory map, a lithological map, a severity of erosion map and finally a map showing land capability classes, which is in effect a plan showing the optimum use of land. Classes I, II and III are sufficiently safe for grassland farming, and class IV which covers 78% of the area of the catchment, requires some remedial treatment. This class would probably correspond with the land category 'Land in which there is slow deterioration' of Grange and Gibbs. Classes V and VI are regarded as beyond the scope of conventional soil conservation treatment and it is in these areas, which amount to 8% of the catchment, that the most severe erosion occurs.

Hamilton and Kelman went further than an erosion survey and suggested recommendations, the effect of which is to incorporate soil conservation measures in farming practice. It is probable that in time this principle will be recognised and adopted.

Soil Conservation

The world-wide publicity focussed on soil erosion and soil conservation in the decade 1930-40 received acknowledgment in New Zealand with the passing of the Soil Conservation and Rivers Control Act, 1941. The Act gave recognition to the fact that the catchment is a natural, geographic unit in which the high country cannot be divorced from the lowlands. To give practical effect to the Act, the country was divided up into a number of catchment districts each with its own local authority, the Catchment Board. The local authority for the Gisborne-East Coast region is the Poverty Bay Catchment Board set up in 1945 and one of its first tasks was to institute flood protection measures on the highly fertile, highly productive lowland, the Gisborne Plain on which over 600 settlers follow agricultural and pastoral pursuits. To control the Waipaoa River, a large stop-banking scheme, costing over New Zealand £ 1,000,000 is now well under way. At the same time, experimental work was undertaken in the headwaters of Waipaoa River with the object of reducing the flow of rock debris from gully erosion, but the gullies in the main, could not be contained by small engineering works owing to the instability of the geological formations. The training of waterways by cheaply constructed fascines and groynes has been successful and methods of guiding and fixing of runnels and small water courses on earth flows of bentonitic mudstones offer great promise. One method, is to plant tree cuttings (willow species) in pairs astride the water course and to line the channel with fascines to prevent scouring of trees.

The prevention of gullying in earthflows is most important and where trees have been grown in waterways, stability has been achieved.

The greatest single deterrent to the success of tree planting is the marsupial foxlet or oppossum which kills the trees by eating the new growth.

Conservation work in the region is directed at present to patching up the damage to the land by accelerated erosion, but plans are now being made to start preventative treatment on land which may show little signs of erosion at present but may be capable of erosion in the future. It is likely that many of the gullies will be clothed in trees, the steep slopes dotted with trees, and earthflows covered with small plantations with a grass sward separating them.

The efforts by man to check rock erosion of the shattered Cretaceous formations seem rather puny and it will be necessary to assume a large element of luck in the climate to allow of smothering over of the raw rock by vegetation, natural or otherwise.

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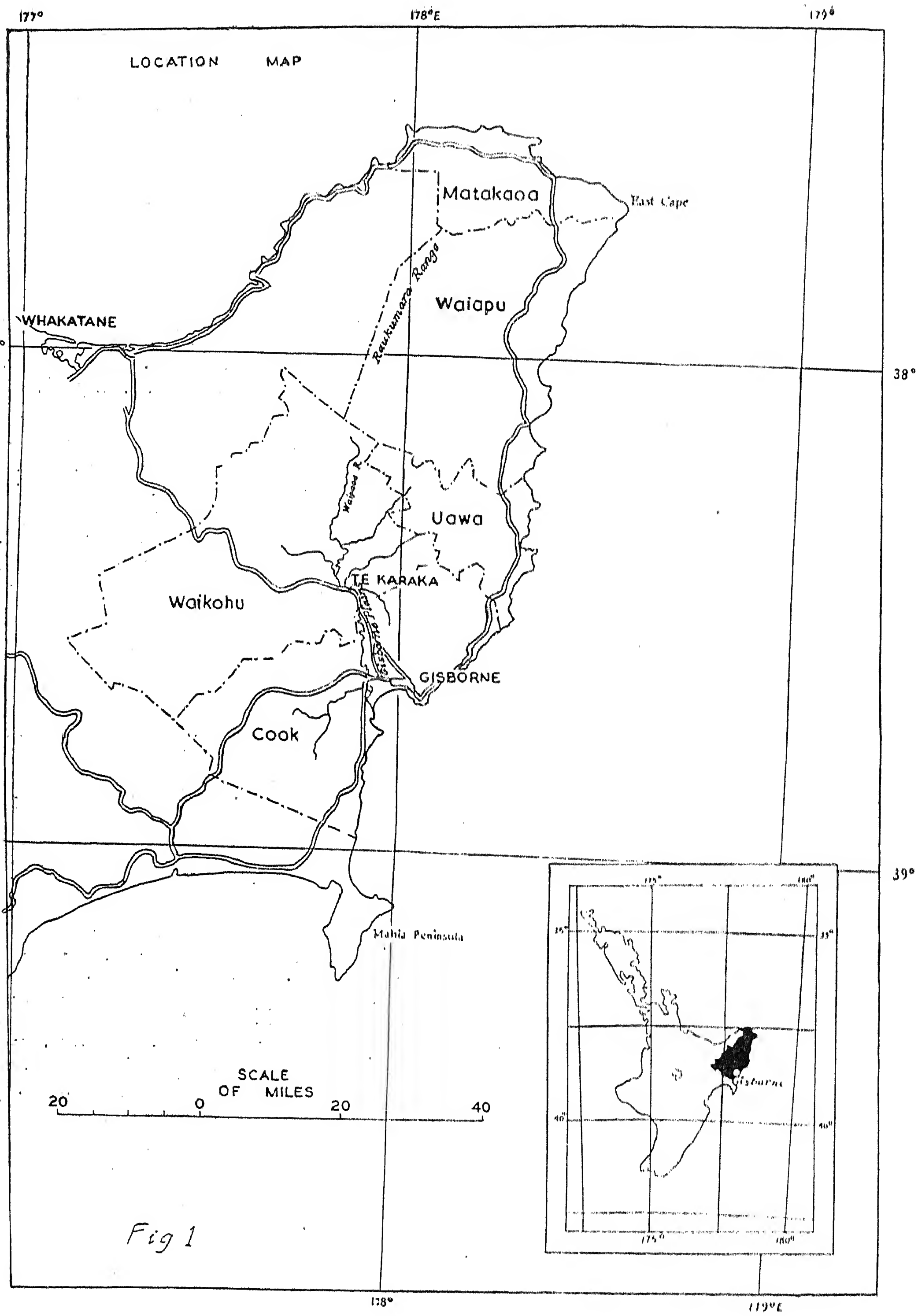
LOCATION MAP
177°
178°E
179°
Matakaoa
East Cape
Raukumara Range
Waiapu
WHAKATANE
38°
Waipaoa R.
Uawa
TE KARAKA
Waikohu
Gisborne Plains
GISBORNE
Cook
39°
Mahia Peninsula
SCALE OF MILES
20
0
20
40
178°
179°E
Gisborne

Fig 1

SECTION—10

LAND CLASSIFICATION AND EVOLUTION

LAND CLASSIFICATION SURVEYS FOR SOIL CONSERVATION PLANNING IN THE DAMODAR VALLEY

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Land classification surveys are the basis for the best fundamental land use adjustment. They are an attempt in a systematic way to assign each area to the use to which it is best adopted physically, economically and socially. For proper land use planning, the first step essential is a soil survey based on the morphology and chemical characteristics of the soil profile, to provide us with an inventory of the soil resources, the basic data, for the fullest development of soil resources. Soil surveys combined with erosion and land utilisation surveys will serve as a basis which with the superimposition of economic factors will result in a practical land use classification that will enable us the full exploitation of the soil resources, consistent with the maintenance of the soil productivity on a permanently high level. Such a land capability classification is based on the general suitability of the land for cultivation, or for permanent vegetation keeping in mind the danger of erosion.

In classifying land according to its use capabilities, four groups of physical factors considered are :—

(*i*) Erodibility of soil,

(*ii*) Productivity of soil, as conditioned by inherent fertility, water holding capacity, salt content, depth, texture and permeability, etc.

(*iii*) Presence of any other factor that would interfere with the use of land, as varying slopes, stoniness or a hard pan layer.

(*iv*) The climatic environment.

The best use of land is one under which the soil will deteriorate the least and will produce the maximum.

Grouping together soils physically suited for a given type of vegetation produces a classification called land capability classification. It is based on the capacity or potentiality of the land to produce. It does not necessarily reflect the present state of land, which may require the application of conservation measures or other treatments to bring this into condition which will make it permanently productive. On the other hand if conservation practices are not able to transform an area into a more permanently productive condition that land must remain in a less useful class.

Land classification surveys in the Damodar Valley have been und.rtaken on a catchment-wise basis, to prepare land capability maps for soil and water conservation planning including recommendations for erosion control on the uplands, denuded forests and gullied lands, which contribute most to the erosion menace. Such surveys in the valley include the following three types of surveys.

A. Soil Classification Survey.

B. Erosion Survey.

C. Land Utilisation Survey.

A. SOIL CLASSIFICATION SURVEY

Soil survey is a method for the examination, classification, delineation and study of soils in the field. Air photographs on a 6″ to a mile scale are being used as base maps. Soil profile is the unit of study. The position of every soil profile is fixed on the photographs by the principle of traversing. The traverse is begun from or located in reference to a known point, compass bearings can be used for knowing the direction, and the distance may either be paced or measured by a chain, Location of profiles on photos can be fixed by reference to trees, road crossings etc.

Soil profile 4′ x 4′ is excavated to the depth of decomposed parent rock, or the depth necessary to identify the soil with certainty (4-6′), and allowed to stand for a few days before study to allow better structure identification. Profile site is selected in the central position of an apparently uniform soil area. The following soil characteristics are noted with a note on the environment (relief, drainage, physiography, and vegetation). Natural system of soil classification is used, which is based on soil morphology (all observable relevant characteristics) pointing to the genesis of soils with adequate laboratory analysis. Soil characteristics of profile studied collectively are :—

(*a*) Colour of each horizon.

(*b*) Soil structure of each horizon.

(*c*) Structure of each horizon.

(*d*) Consistence of each horizon.

(*e*) pH of each horizon.

(*f*) Occurrence of ferruginous or siliceous concretions in any horizon.

(*g*) Occurrence of organic matter in any horizon including plant roots.

(*h*) Soil depth.

(*i*) External and internal drainage.

(*j*) Nature of parent material of profile.

Since no two soil profiles even of the same soil type will be entirely identical (but will have certain differentiating characteristics in common) a model profile with allowable range in the profile is established for each soil type. The same kind of horizons are present in all of the profiles of the group and they occur in almost the same sequence. Soil type properties vary within defined limits. Each soil type is examined and described at several points. Soil boundaries are usually diffuse or gradual and may be indicated sometimes by a change in colour, topography, textute of surface soil. soil depth, and sometimes by vigour or species of vegetation. Soil type bounda.ies may be deduced by interpolation of evidence of soil profiles. Boundaries are plotted from observations made throughout their whole course.

B. EROSION SURVEY

Soil erosion map should form a base for any planning. Basically erosion surveys classify and combine four different factors, namely, soil type, land use, slope and erosion. Soil erosion types are influenced by physiographic features and land

utilization practices. Since in Damodar valley area the topography is very undulating and rolling and undisturbed area is not available except within a reserved forest, the selection of a 'reference' profile for each soil type is essential in mapping the degree of soil erosion. Such a reference profile for each soil type is selected after due consideration of micro-relief of the areas occupied by that soil type, as comparisons are to be made on comparable slopes. The erosion is estimated by weighing other profiles of the same soil type in an area with the reference profile of that soil type. Erosion is a more complex function of slope, and is essentially a phenomenon of a catchment unit. Hence measurements of slopes are included in an erosion survey. Topographic maps may be very helpful.

The following erosion classes are mapped in the Damodar valley :—

Symbol	Erosion classes	Description
0	No apparent erosion	...
1	Slight sheet erosion	<25 % of solum removed
2	Moderate sheet erosion	25-75 % solum removed
3	Severe sheet erosion	>75 % solum removed
7	Occasional gullies	Gullies 100′ apart
8	Frequent gullies	Gullies 100′ apart
9	Very severely gullied.	...

In case of the gullies in addition to frequency, the depth, width, and catchment area of gullies are mapped.

(i) Classification of gullies according to depth :

Symbol	Description	Control measures
a	<1′ deep	Ploughing up
b	1-3′ deep	Sodding & seeding (Biological control)
c	3-5′	Temporary mechanical measures like gully plug, brush dam, etc.
d	5-10′	Masonary measures like check dams with spillway.
e	>10′	Possibility of storage (conservation pond).

(ii) Classification of gullies according to width :

Width of gully at the ground level, not at bed level is to be considered. This will be necessary to prepare estimate of the control measures recommended. This is sub-divided into 2 groups :

Symbol	Description
X	<10′ wide
Y	>10′ wide

(iii) Classification of gullies according to catchment area of gully :

This item is mapped in respect of gullies which are more than 3′ deep, so that

control measures can be designed properly. This is sub-divided into the following classes :—

Symbol	Description of catchment
i	25 acres
ii	25-50 acres
iii	50-100 acres
iv	100 acres.

C. LAND UTILISATION SURVEY :

The purpose of land utilisation survey is to map the present use of land, the use to which the lands are being put at the time of survey, to provide us the basic data to enable preparation of land utilization plan to avoid further misuse of land by putting the land to the best economic use.

The following major land use categories are used in mapping the present use of land :—

(*a*) Crop land
(*b*) Pasture
(*c*) Forest
(*d*) Wasteland
(*e*) Orchard and plantation
(*f*) Water bodies (tank, reservoir, etc.)
(*g*) Mining
(*h*) Settlements

Each of the major categories is sub-divided, *e. g.*, crop land into paddy and uplands. Similarly the other categories of land use are sub-divided and mapped. These are shown by suitable symbols and colour combinations on the maps.

For classification of land based on quality, four types as distinguished and mapped on the basis of inherent soil characteristics, like soil depth, drainage, permeability, stoniness, and associated land factors, like, availability of water are :—

(*i*) Good land
(*ii*) Medium land
(*iii*) Marginal land
(*iv*) Poor land

For the specific environmental and agricultural conditions in the valley, only 'four' Land Capability Classes have been worked out. These are :—

Class I—Very good land, level or nearly level with little or no erosion. Easily worked and safely cultivated with ordinary good farming methods, like, fertilization and crop rotation.

Class II—Good land, usually upland with slopes 0-3%, moderate sheet erosion but safely cultivable with easily applied soil conservation practices like, contouring, protective cover, graded channel terrace and simple water management practices.

Class III—A few low to medium gullies or slopes exceeding 3%, soil heavy and deep, slopes moderately or severely eroded. Readily reclaimable by mechanical or other measures, and made into terraced paddy fields.

Class IV—Lands not suited for cultivation but suited for forest with careful management with contour ditching, diversion dykes or terraces, and good silvicultural practices. Soils shallow and very erodible. Very steep, stony, rough, sandy or severely eroded.

Since social and economic conditions greatly affect the use of land, the above classification according to physical capability cannot be used directly for recommending land use. For example, a good plot of land with 1-3 % slope could be cultivated with simple conservation practices, but has a flourishing forest. Though this upland could be used for cultivation, it is preferable to keep it under forest growth, as forest growth of a significant size always takes time. Thus even if the land capability class of this area is Class II, its land use class will be forest, *i.e.*, land use Class IV.

Similarly a piece of land with heavy and deep soil with a slope of 3-4 % but eroded by deep gullies can be made into a good terraced paddy field, but the amount of earth work involved makes the cost high and prohibitive, this land though Land Capability Class III must go to forest, *i.e.*, Land Use Class IV.

For the conditions of the valley, the following four land use classess have been worked out :—

1. Paddy (Terraced fields)
2. Upland
3. Pasture
4. Pasture-cum-forest or forest.

This classification is primarily directed not only to conservation but greater food production. Paddy is the main crop and a land use is called paddy. It does not mean that no other crop can be grown on these terraced fields. Rabi crops will do well on these soils provided water supply is assured.

SUMMARY

Land classification according to use capability are based on the physical land characters together with their environment and expressed in terms of the restrictions in uses or practices and measures necessary for the most intensive utilization that is consistent with the preservation of the soil and its plant cover.

Land classification surveys for soil and water conservation planning are being conducted in Damodar valley on the air photographs on 6″ to a mile scale. Such surveys provide us the basis for the preparation of land capability maps. On the basis of land capability maps, the fairly well-known methods of soil and water conservation measures will be adopted on the various classes of land. Such land classification surveys are of great importance in the elucidiation of many of the problems of land utilisation.

Such capability is determined by an appraisal of soil. erosion, and land use in their collective relation to the capacity of land to produce. To suggest appropriate use of an area of land it is essential to have a clear picture of general erosion condition, land use and soil types.

The soil and water conservation measures will include irrigation facilities for paddy fields, afforestation of waste and unproductive lands, contour ditching and graded channel terrace for uplands, reclamation of waste lands for upland cultivation, pasture and conservation of gullies will include gully control as well as their reclamation as paddy fields or their afforestation according to their suitability.

SOIL CLASSIFICATION AND SOIL MAPPING IN NAINITAL TARAI

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With a view to increase food production and to rehabilitate ex-servicemen and displaced persons the Government of Uttar Pradesh started in 1948, at the instance of the Government of India, a scheme for the reclamation and colonization of the sub-montane tract called Tarai and *Bhabar* in the State. The sub-montane tract in U. P. starts as a belt below the Himalayas from the district of Dehradun to that of Deoria. In the first instance the reclamation and colonization work started in the tarai areas of the district of Nainital. Previous to this reclamation work, the tarai areas were characterised by extreme unhealthiness caused due to excessive soil moisture and prolific growth of tall grassy vegetation. The soils were known to be fertile but inspite of this the tract remained uncultivated and un-inhabited due to severe outbreaks of malarial academics, inaccessibility and depredations of wild animals. With the help of heavy mechanical equipments the area was cleared of the forests and attemps were made, with the help of insecticides, to control malaria. Roads were built connecting the area with the neighbouring districts. The cleared upland was divided into suitable plots and allotted to ex-servicemen or displaced persons. In order to help the progress of rehabilitation, three big mechanised farms were also started in the area under the direct supervision of the Government. Each of these farms occupies an area of 5,500 acres and are known as the Western, Central and Eastern blocks of Tarai State Farms which have their headquarters at Matkota, Phoolbagh and Nagla respectively.

Since the above tract was obtained as a result of reclamation no information in regard to the soils of the area was available. Accordingly the State Soil Survey Organization of the U. P. Government took up a detailed soil survey and soil mapping of the entire Tarai State Farms with a view to knowing the characteristics, fertility status, agronomic and fertilizer requirements of the various soil types met with in the area. The present paper gives an account of such a survey carried out at the Western block, Matkota of the Tarai State Farms in the Nanital tarai. This work was conducted from the Government Regional Soil Laboratory, Rudrapur (Nainital) under the supervision of the staff of the Agricultural Chemistry Section at Kanpur.

METHODS OF SURVEY

Soil samples were drawn by means of post-hole augers by parties of two assistants and the samples were collected, both for surface, *i.e.* 0-9 inches, and the sub-soil ranging from 9 to 18 inches. From each plot of 25 acres four such borings were made at equal intervals of 110 yards each in a north to south direction. Soil samples from each of the plots were composited separately for the surface as well as the sub-soil layers, if no soil heterogeneity was observed in the individual samples. For such plots, therefore, only two samples were ultimately collected. In case

where soil heterogeneity was observed in individual plots, soil samples were collected separately for each boring and, after field observations, were separately brought to the laboratory for detailed analysis. Since in a small area major soil differences are not likely to be much, the soils were examined only for such specific tests which may bring out distinctive characteristics for classifying them and for determining their nutrient status or land-use capabilities.

The soil samples were examined for texture, colour, reaction, lime content, organic matter, nutritional status and soil depths. In all about 700 samples were collected from the entire farm. The detailed mechanical composition was determined for about 65 plot samples selected at random, from the entire area which represented all the soil associations found on the farm.

THE SOIL TYPES OF THE AREA

The study has revealed the presence of three major soil textural groups with three sub-groups under one of the main group. The main textural groups are (*i*) clay loam, (*ii*) loam and (*iii*) sandy loam. The loamy group has been further sub-divided into three classes depending on its lime status *viz.*, (*i*) loam with enrichment of lime (*ii*) loam with minor quantities of lime and (*iii*) loam free of lime. The sandy loam soil groups also contain some predominantly sandy soils which have not been separately classified due to their allied crop responsiveness and extreme intermixing in even very small areas. The farm thus can be divided into the following five textural-cum-calcimorphic soil associations.

1. Matkota clay loam.
2. Matkota loam—highly calcareous.
3. Matkota loam—slightly calcareous.
4. Matkota loam—non-calcareous.
5. Matkota sandy loam.

The distribution of these soil types has been shown in the attached soil map of the farm (Figure 1). In table I has been given the extent of each soil type as mapped and its percentage to total area of the farm.

TABLE I

EXTENT OF SOIL TYPE IN THE AREA SURVEYED

Soil Type	Colour	Area of soil type (acres)	Proportion of area (per cent.)
Matkota clay loam	Dark Gray	625	11·3
Matkota loam (highly calcareous)	Dark Gray brown	725	13·2
Matkota loam (Slightly calcareous)	Gray brown	1,275	23·1
Matkota loam (non-calcareous)	Gray brown	925	17·0
Matkota sandy loam	Dark brown	1,950	35·4

The following is a brief description of the five soil types found and mapped on the farm. Under each soil type there is a description of the soil as observed in the field. Some indications of broad fertilizer requirements and crop adaptability have also been given for the various soil types.

Table 2 contains the data on the analysis of a typical profile from these soil types, except Matkota loam non-calcareous, which show the differences on which the classification is based.

TABLE 2

ANALYSIS OF TYPICAL PROFILES OF MATKOTA FARM
(Per cent. air dry basis)

Lab. No.	Depth (inches.)	Coarse sand.	Fine sand.	Silt.	Clay.	pH	Organic carbon.	Total nitrogen.	C/N.	CaO	Base exchange capacity m. e.
					MATKOTA CLAY LOAM.						
T715	0-8	0·88	20·03	51·63	25·20	7·5	1·63	0·178	9·1	0·97	14·73
T716	8-16	0·86	21·14	54·10	23·90	6·8	1·02	0·091	11·3	1 20	12·18
T717	16-25	0·56	13·73	59·15	24·00	7·2	0·80	0·060	13·4	1·04	11·98
T718	25-38	1·44	14·01	56·70	26·70	7·0	0·78	0·083	9·4	1·02	11·73
T719	38-54	0·55	11·44	65.98	21·13	6·9	0·61	0·071	8·5	0·91	10·48
T720	54-72	0·31	18·90	57·75	21·50	7·1	0·52	0·056	9·2	0·84	9·22
					MATKOTA LOAM—HIGHLY CALCAREOUS.						
T711	0-9	7·87	31·35	33·60	25·00	7·2	1·23	0·126	9·8	2·41	15·78
T712	9-23	2·63	39·39	35·75	19·75	7·2	0·84	0·083	10·1	5·51	13·05
T713	23-28	0·86	33·27	48·20	15·00	7·4	0·45	0·042	10·7	2·87	6·79
T714	28-38	6·25	26·54	47·50	18·20	7·6	0·44	0·039	11·3	1·06	9·11
					MATKOTA LOAM—SLIGHTLY CALCAREOUS.						
T721	0-9	2·30	20·34	45·18	29·65	7·3	0·72	0·070	10·3	1·64	11·68
T722	9-15	4·55	27·05	38·00	28·00	7·3	0·89	0·085	10·5	1·08	14·07
T723	15-24	5·08	30·61	37·80	24·00	7·5	0·99	0·094	10·5	0·66	15·26
T724	24-32	1·35	17·90	49·20	30·70	7·6	0·62	0·057	10·9	1·19	11·68
					MATKOTA SANDY LOAM						
T727	0-9	25·50	45·30	15·60	12·22	7·4	0·81	0·059	13·7	0·45	10·80
T727	9-18	29·28	43·60	12·33	12·80	7·2	0·62	0·055	11·2	0·60	8·80
T728	18-32	35·28	42·22	10·30	10·40	7·2	0·36	0·039	9·2	0·42	8·80
T729	32-39	36·17	51·52	5·88	3·92	6·8	0·23	0·017	13·5	0·31	7·60
T730	39-51	28·92	55·02	9·18	4·45	6·7	0·21	0·029	7·2	0·38	8·40
T731	51-72	4·51	73·60	9·80	11·20	6·5	0·18	0·021	8·5	0·57	8·40

(1) *Matkota clay loam.* Matkota clay loam is the least extensively occuring soil type on the farm. The total area under this soil type comes to 625 acres which is only 11·3 per cent. of the total area. It is found in comparatively lowlying micro-relief of the farm and occurs on the south-west side of the new road from Rudrapur to Nagla. Another fairly big sized continuous patch has been located on the northern side of this road behind Patharchatti.

This soil type is very mildly calcareous in nature throughout the depth of the profile. Texturally it is clayey loam tending to be silty clay loam and is rich in organic matter with a dark gray colour at the surface. The surface layer extends, on an average, to a depth of 16 inches but in some cases it may go as deep as

24 inches. The next layer consists of a light yellowish brown material with a silty loam texture and with comparatively low organic matter. The entire profile is characteristised by a low sand content, both coarse and fine, which gives to this type an unusually high water holding capacity and high base exchange values. It is somewhat poorly drained soil.

In regard to the nutrient status of the soil type it may be stated that the soils are very mildly alkaline, pH value ranging from 6·8 to 7·5. This gives this type an inherent character of richness in bases. The organic matter content is high and so also is total nitrogen. Carbon-nitrogen ratio of these soils is slightly less than 10. The soil type appears to be particularly deficient in available phosphoric acid and this deficiency becomes all the more pronounced due to its inherent richness in nitrogen. Moderate dressings of phosphatic fertilizers in conjunction with light doses of nitrogenous artificials or even phosphate alone as such are likely to produce very beneficial results in increasing crop production. The reserves of nitrogen and organic matter which are present at the moment are likely to be depleted at a very fast rate specially under mechanised cultivation unless some measures for maintaining humus in the soils are introduced in crop rotation. Obviously green manuring once in three years in a rotation of paddy sugarcane or paddy wheat seems to give desirable results. Dhaincha may be tried as a suitable green manuring crop for this soil type in view of its clayey texture and water logged nature. This point should be tested further in long term rotational experiments since the management of the fertility of this soil type on this farm is extremely essential as it is one of the most valuable soils found in the course of this survey.

This soil type is suited to practically all crops excepting those which do not thrive well on heavy soils. Paddy, gram, wheat and sugarcane are likely to give most economical returns.

A morphological description of a Matkota clay loam soil profile is given below :

LOCATION. Plot No. 171 Matkota State Farm, Rudrapur.

IRRIGATION. Tube well.

TOPOGRAPHY. Low lying but levelled.

NATURAL VEGETATION. Tall grass.

WATER TABLE. 5 to 6 feet.

MORPHOLOGICAL HORIZONS.

0-8″ 8″-16″	Dark gray (5YR 4/1 ; 10R 9/3 moist) ; clayey loam to silty loam with moderate fine crumb structure ; sticky and plastic while wet becomes friable on drying ; mildly alkaline and calcareous ; rich in organic matter with grass roots visible.
16″-25″ 25″-38″ 38″-54″	Light olive gray (5Y 6/2 ; 5Y 3/1 moist) ; clay loam to silty loam; strong very fine crumb structure ; sticky and slightly plastic when wet ; friable on drying ; neutral in reaction and small calcareous concretions (*chharries*) present ; roots absent.
54″-72″	Light yellowish brown (10YR 6/4 ; 5/2 moist) ; silty loam ; strong very fine granular structure ; sticky and slightly plastic when wet, soft and friable while dry ; neutral reaction ; small calcareous nodules present ; roots absent.

(2) *Matkota loam-highly calcareous.* Matkota loam, highly calcareous, soil type is also not a very extensive type in the western block of the Tarai State Farms. It aggregates a total area of only 725 acres which works out to 13·2 per cent. of the total acreage. It occurs on both sides of the new road towards the central portion with a small patch at the western side of Matkota clay loam in the north. Isolated patches are also found in the north-eastern portions of this block.

The soils are highly calcareous throughout the depth, lime contents being more than that in the clayey loam type. Upper nine inches of the soil is loam in texture with a dark gray brown colour and is rich in organic matter. This layer is underlain by a lighter textured layer which is gray brown in colour with comparatively less organic matter. The sub-soil is pale brown in colour and poor in organic matter and nitrogen. The soil profile contains greater quantities of coarse sand and is situated at slightly flatter topography which gives it somewhat better drainage conditions.

The organic carbon and total nitrogen contents are high in the surface and sub-surface layers but fall very rapidly in the sub-soil. The total phosphorus content is high but available phosphoric acid is low. The soils are very mildly alkaline the pH values varying between 7·2 to 7·6, giving it an adequate reserve of bases. Total exchange capacity is fairly high specially in the surface layer. The carbon nitrogen ratio remains near about 9 at the surface and slightly broadens in the lower depths. These soils like their clay loam counterparts are expected to give good response with dressings of phosphatic fertilizers in conjunction with light nitrogenous doses. Preliminary experiments conducted on this soil type have indicated the desirability of this type of fertilizer practice to build up soil fertility at a high level. The effect of phosphate application on this soil type would be of a lasting nature and is expected to give residual responses on two or three subsequent crops. The excellent reserve of nitrogen and organic matter in this soil, however, should be carefully preserved as these are liable to be lost rather fast under the present system of mechanised cultivation.

Green manuring with *sanai* or *dhaincha,* at least once in three years, will considerably help in maintaining or even building up the fertility status of these soils.

The soil type is suited for almost all crops but paddy, wheat and sugarcane are likely to do very well. Introduction of leguminous catch crops in the rotation will further improve the crop producing capacity. The nature of these soils is such that crops can be grown without irrigation, but in view of the prevailing cultivation practices which deplete the moisture content through deep mechanised cultivation, light irrigation may become necessary as the water holding capacity is progressively reduced. These soils are likely to show good drought resistance till such time as the organic matter in them is markedly reduced.

Below is given the morphology of a Matkota loam highly calcareous soil profile :

LOCATION. Plot No. 68 Matkota State Farm, Rudrapur.

IRRIGATION. Unirrigated.

TOPOGRAPHY. Flat and levelled.

NATURAL VEGETATION. *Kans*

WATER TABLE. 10 to 12 ft. in summer ; 3 ft. in monsoon.

MORPHOLOGICAL

Horizons

0-9″ Dark gray brown (10YR 4/2 ; 3/2 moist) ; loam ; moderate fine crumb structure ; sticky and plastic when wet ; friable on drying ; soft ; neutral in reaction ; calcareous ; organic matter medium ; plant roots present.

9″-23″ }
23″-28″ } Gray brown (10YR 5/2 ; 4/2 moist) ; sandy loam ; weak mediums, single grained structure ; non-sticky and non-plastic ; neutral reaction ; small calcareous nodules (*chharries*) present.

28″-38″ Pale brown (10YR 6/3 ; 5/2 moist) ; loam ; weak single grained structure ; sticky slightly plastic loose and soft when moist but friable when dry ; mildly alkaline ; no concretions ; roots absent.

(3) *Matkota loam-slightly calcareous.* This soil type occurs more extensively than the other two soil types described earlier and is the second largest occuring soil type on the farm. The soils are found mostly scattered in the western and towards the central portions of this block. Some patches are also found in the northern and the eastern parts of the farm. The soils occur at slightly elevated regions and occupy a total acreage of 1275 acres. This comprises 23 per cent. of the total area of the farm.

This soil type due to its slightly elevated situation is poorer in lime contents. It is loam to silty loam in texture on the surface and is gray brown in colour. The depth of the soil layer is only upto 24 inches where adequate reserve of organic matter seems to be present. The lower layers are lighter in colour and the soils at 32 inches depth assume a pale brown hue. The texture of the intermediate layer is loam while that of the lower layer is silty clay loam. Coarse sand particles have appeared in the soil in contrast to the clayey loam type showing calcareous nature. The richness of sand particles renders the soil type to exhibit lower water holding capacity. Base exchange capacity of these soils is somewhat lower than the former soil types but in the lower regions of the soil profile it is of the same order. The base status of the exchange complex is also poorer as compared to the calcareous soil.

The nutrient status of this soil type is poor. The organic matter contents are considerably lower and total nitrogen follows the distribution of organic carbon. Carbon-nitrogen ratio ramains almost constant at about 10·4. The pH of the soil ranges towards mildly alkaline side. Available phosphate content is low and this fact substantiated by the raw nature of the humus inevitably leads to the conclusion that ideal manurial supplement for this soil type will be light dressings of both nitrogen and phosphoric acid.

In view of the inherent danger of the depletion of organic matter frequent green manuring practices should be adopted. Both *dhaincha* and *sanai* can thrive well on these soils though the former may behave erroneously during the years of low rainfall. *Sanai* thus seems to be a more suited green manure crop for this soil type. The soil type is more suited to crops like maize, wheat and paddy. During *rabi* mustards may prove to be highly profitable crops. Introducing some leguminous crops during *kharif* is also advisable.

Deep mechanised cultivation is liable to bring deterioration of moisture status and loss of reserve organic matter. Light cultivation is expected to be ideally

suited for this soil type. Irrigation facility constitutes one of the prime necessity of good management on this soil type. The morphology of a representative profile is given below :

LOCATION. Plot No. 203 Matkota State Farm, Rudrapur.

IRRIGATION. No irrigation.

TOPOGRAPHY. Level.

NATURAL VEGETATION. *Kans* and *Narkul.*

WATER TABLE. 10 ft. in summer ; 5 ft. in monsoon.

MORPHOLOGICAL

Horizons

0-9″ Gray brown (10YR 5/2 ; 4/2 moist) ; loam ; strong medium granular structure ; slightly sticky and plastic when wet ; soft and friable when dry ; neutral reaction ; no concretions ; rich in organic matter ; roots present.

9″-24″ Gray brown (10YR 5/2 ; 4/2 moist) ; loam ; weak medium granular structure ; non-sticky ; slightly plastic ; soft and friable ; mildly alkaline ; concretions absent ; no roots present.

24″-32″ Pale brown (10YR 6/3 ; 5/2 moist) ; silty clay loam ; moderate fine granular structure ; sticky and plastic ; mildly alkaline ; clay pan present.

(4) *Matkota loam non-calcareous.* The extent of the area under this soil type amounts to 925 acres and accounts for 17 per cent. of the total area. The soils are found mainly distributed in the central, southern and north-eastern corner on both sides of Rudrapur Nagla Road, some patches are also found in the central and south-eastern parts.

This soil type possesses a loam to sandy loam texture at the surface which get heavier in the lower depths. The bottom layers below 36 inches are sandy loam or even sandy at times. The soils are grayish brown in colour but the lower layers get darker in shade. The intermediate layers are dark gray brown and the bottom layers are yellowish brown in colour. The soil profile thus presents a transitionary soil type between the Matkota loam-slightly calcareous and Matkota sandy loam soils. They have a poor water retentive capacity and are not very suitable for growing crops specially in absence of irrigation. The soils have average plant nutrient status. Organic matter contents are average to high and so is the case with total nitrogen. The C/N ratio is low. These soils can thus retain their nutrient status and will respond well to all cultural and manurial treatments. The available phosphate contents are medium. These soils require application of both phosphatic as well as nitrogenous fertilizers in long term fertility maintenance.

The lighter texture of the soils makes water requirements of this soil type comparatively higher. Arrangement for regular irrigation should thus be made on this area. The cultivation practices for this soil type should be limited to light cultivation through the help of light implements and tractors with shallow ploughing devices. Disturbance of sub-soils will prove deterimental in long term use and

soil building will be hampered. The morphology of a profile of this type is described below :

LOCATION. Plot No. 192 Matkota State Farm, Rudrapur.

IRRIGATION. No irrigation.

TOPOGRAPHY. Slightly high lying.

NATURAL VEGETATION. *Kans* and *Makra makri.*

WATER TABLE. 14 ft. in summer ; 6 ft. in monsoon.

MORPHOLOGICAL

Horizons	
0-9″	Gray brown (2·5Y 5/2 ; 4/2 moist) ; loam, moderate medium granular structure ; non-sticky ; slightly friable ; neutral in reaction ; non-calcareous ; roots present ; rich in organic matter.
9″-22″ } 22″-36″ }	Dark gray brown (2·5Y 4/2 ; 3/2 moist) ; loam to clay loam, strong medium granular structure ; sticky and plastic ; compact than above ; non-calcareous ; neutral reaction ; medium organic matter.
36″-54″	Yellowish brown (10YR 5/4 ; 4/2 moist) ; sandy loam ; structureless ; non-sticky ; non-plastic ; loose friable non-calcareous neutral reaction ; organic matter absent.

(5) *Matkota sandy loam.* Matkota sandy loams are the most extensively occurring soils of the western block of Tarai State Farms. These soils are widely found in the north-western portion and also in the south-eastern side of the farm. Scattered patches are found in the north-east and central portions towards the right side of Nagla Road at some distance from Patharchetta. This type covers an area of 1950 acres and accounts for about 35 per cent. of the total farm acreage.

The soils are sandy loam to sandy in texture and are dark brown to reddish brown in colour. There appears to be very little proportions of finer fractions and accordingly power of soil aggregation is almost completely absent from these soils. The entire profile from top to bottom has practically the same sandy texture, rather the lower layers contain higher proportion of coarse sand. No depth of good soil is thus present and therefore the soils are liable to suffer from droughty conditions, as the rate of percolation of water in these soils is excessive. The water holding capacity has been found to be very low. Organic matter contents are also low specially in the lower regions. The surface layer, however, has got some reserve of organic matter which is not likely to last long under intensive cultivation. The exchange capacity of these soils is low as is common with soils of low clay contents.

The nutritional status of these soils is also very poor and C/N ratio is broad. This shows very low proportions of nitrogen contents in the soil. These soils have medium to high contents of available phosphate and responses with phosphatic fertilizers can only be expected when supplemented with heavier nitrogen doses. At times phosphate application may not be beneficial to the extents found in other soil types but nitrogen dressings will always yield encouraging increases. The poor aggregation of the soil makes it necessary to include annual green manuring with *sanai* in the soil management practices for this soil region.

These soils in fact are not very suited to agricultural crops and should be best utilised for pasture. Besides this use only crops like small millets *e.g., madua*

and *jowar* can satisfactorily grow during *kharif*. During *rabi* only oats will give good results but barley may also be tried in patches with improved aggregations. It may, however, be noted that water requirements of these soils is very high and in any scheme of soil management provision of frequent irrigation for this area must be made. With adequate manuring and supplies of irrigation water good crops may be obtained on this soil type. The soils are very thin and deep ploughing is contra-indicated. Perhaps a year or two of sod followed by a year or two of cultivation may help to build the soil further and improve crop production.

A profile of this type has the following characteristic morphological features.

LOCATION. Plot No. 113 Matkota State Farm, Rudrapur.

TOPOGRAPHY. Undulated, sloping to west.

IRRIGATION. No.

NATURAL VEGETATION. *Makra makri.*

WATER TABLE. 18 ft. in summer ; 7 ft. in monsoon.

MORPHOLOGICAL

Horizons

0-9″ Dark brown (10YR 4/2 ; 5/3 moist) ; sandy loam ; weak very coarse structure ; non-sticky and non-plastic ; loose, neutral in reaction ; no concretions ; rich inorganic matter ; roots present.

9″-18″ Grayish brown (10YR 5/2 ; 4/2 moist) ; sandy weak very coarse structureless ; non-sticky ; non-plastic and loose ; no concretions ; neutral in reaction ; few thin roots present.

18′-32″ Yellowish brown (10YR 5/4 ; 4/2 moist) ; sandy ; weak very coarse, structureless ; non-sticky ; and non-plastic ; loose, netural in reaction ; no concretions.

32″-39″, 39″-51″, 51″-72″ Yellowish brown (10YR 5/4 ; 4/2 moist) ; coarse sandy ; structureless ; non-sticky ; non-plastic ; very loose ; slightly acidic reaction ; no concretions.

HOW TO MAINTAIN SOILS AND INCREASE CROP YIELDS

The soils of Matkota farm are young and immature and satisfactory crop yields year after year are possible only through good soil management and favourable weather conditions. At the Matkota farm the proportion of first class soil of good productivity is not very large. Matkota clay loam and Matkota loam-highly calcareous, which together may be taken to represent good quality soils on the farm, occupy only 24·5 per cent. of the total area. Matkota sandy loam, which is a thin soil and has not in it much reserves of nutrients, is fairly extensive occupying about 35·4 per cent. of the land. The rest of the land amounting to about 40 per cent. of the area, is an average quality soil. It is, therefore, essential that the productivity of the good quality soil is maintained and that of the poor quality one built up to higher levels before satisfactory crop yields can be expected over a number of years.

Good soil management refers to such practices as a good choice and rotation of crops, adapted and tried improved crop varieties, application of fertilizers or other amendments where needed, good tillage practices and effective weed, diseases and pest control. A short term or long term rotation containing legumes should

be used on all the soil types of the farm. This practice will provide enough organic matter and nitrogen and improve the physical condition of the soils. A deep rooted legume, like *dhaincha*, if turned under will help much to prevent loss of soil organic matter. Attempts should be made to select out proper legumes for the various soil areas and adopt those that succeed in the actual cropping programmes.

FERTILIZER REQUIREMENTS OF TARAI SOILS

The use of commercial fertilizers on the farm is likely to produce beneficial results. As is evident from Table 2 the soils are of calcareous origin with a very mild alkaline reaction and no liming is required. The nitrogen status of the soils is high and majority of the soils lie in the range of nitrogen contents from 0·08 to 0·125 per cent. This nitrogen content is very satisfactory for crop production. The distribution of nitrogen and available (CO_2-soluble) phosphorus contents of soils from Matkota Farm is given in Tables 3 and 4.

TABLE 3

NITROGEN CONTENT OF MATKOTA FARM SOILS

Soil Type		Total number	0·04-0·06	0·06-0·08	0·08-0·10	0·10-0·125	0·125-0·150	0·150-0·175	0·175-0·200
Clayey loam soil		7	.	1	2	1	1	2	.
	Sub-soil	5	.	1	1	3	.	.	.
Loam (highly calcareous)	Soil	6	1	.	1	1	1	1	2
	Sub-soil	5	1	.	1	2	.	2	.
Loam (slightly calcareous)	Soil	15	.	.	3	5	3	3	.
	Sub-soil	9	.	1	2	4	1	.	.
Loam (non-calcareous)	Soil	8	.	.	1	3	.	4	.
	Sub-soil	6	.	.	3	2	.	1	.
Sandy loam soil		15	.	3	8	2	2	.	.
	Sub-soil	5	1	3	.	1	.	.	.
Total		81	3	9	22	24	8	13	2

TABLE 4

AVAILABLE PHOSPHOROUS CONTENT OF MATKOTA FARM SOILS

Soil Type	Total Number	Traces	Low	Medium	High
Clayey loam	15	5	10	.	.
Loam highly calcareous	6	1	5	.	.
Loam slightly calcareous	17	12	4	1	.
Loam non-calcareous	8	2	3	2	1
Sandy loam soil	20	6	9	4	1
Total	66	26	31	7	2

Application of nitrogenous fertilizers as a routine practice for all crops and all soil types does not seem to be necessary. But some nitrogenous fertilizer will certainly be required specially for average to poor soil types of the farm. In general the available phosphate status of all the soil types, specially the clay loam and the loams appear to vary from traces to low while the sandy soils have proportions of this nutrient varying from low to medium.

In order to verify these observations obtained from soil analysis, agronomic field trials were laid out on the farm during the three years (1951-54). Some parallel experiments on the fields of the cultivators in the adjoining area were also done to see if the results obtained could have a wider applicability.

Following set of experiments laid down on the various soil types throughout the Tarai area :—

(*a*) Simple field trials with economical doses of nitrogen and phosphoric acid.

(*b*) Experiments with varying doses of phosphoric acid on short duration crops.

(*c*) Statistically designed experiments on major *kharif* and *rabi* crops.

In all the experiments to be described below nitrogen was added as ammonium sulphate on the surface and phosphoric acid as single superphosphate in accordance with the technique developed in this section whereby it is placed 3 to 4 inches deep in bands near the root zone. It is of the utmost importance that this technique is strictly adhered to if reproducible results are desired.

(*a*) *Simple field trials with N and P.* The present position in regard to the simple experiments done to assess the deficiency or otherwise of the principal plant nutrients, *i.e.*, nitrogen and phosphoric acid, is given in Table 5.

TABLE 5

AVERAGE YIELDS OF DIFFERENT CROPS DUE TO FERTILIZER TREATMENTS IN TARAI SOILS
(lbs per acre)

Crop	Period of duration	No. of Expts.	GRAIN Control	GRAIN N	GRAIN N+P	STRAW Control	STRAW N	STRAW N+P	Remarks (doses)
Wheat	1951-53	14	992	1150	1400	2367	3001	3179	N at 30 lbs nitrogen per acre. P at 60 lbs P_2O_5 per acre.
Per cent. over control		...	100	116	141	100	127	134	
Barley	1952-53	2	733	717	932	1402	1740	1940	
Per cent. over control		...	100	98	127	100	124	138	
Oats	1952-53	6	405	496	593	973	1226	1247	Do.
Per cent. over control		...	100	122	146	100	126	128	
Paddy	1951-54	17	1379	1606	1699	3456	4121	4030	N at 25 lbs N per acre P at 50 lbs P_2O_5 per acre
Per cent. over control		...	100	116	123	100	119	117	
Maize	1951-54	3	1103	1117	1250	2617	3447	3607	N at 15 lbs N per acre P at 30 lbs P_2O_5 per acre.
Per cent. over control		...	100	101	113	100	132	138	
Jowar	1953-54	2	1640	1900	2360	25540	28200	30380	Do.
Per cent. over control		...	100	116	144	100	110	119	

the residual effect of the fertilizers. Table 8 contain the data obtained on the wheat crop following the paddy in which marked residual effect of phosphoric acid to the extent of 14 per cent. at 50 lbs level was seen.

TABLE 7

EFFECT OF NITROGENOUS AND PHOSPHATIC FERTILIZERS ON RABI AND KHARIF CROPS

(lbs per acre)

TREATMENTS	Year	N_0	N_{30}	N_{60}	P_0	P_{60}	P_{120}
Wheat grain	1952-53	1806	1891	1782	1591	1855	2033
Per cent. over control	...	100	105	99	100	117	128
Wheat straw	1951-52	4020	4471	4555	3691	4662	4693
Per cent. over control	...	100	111	113	100	126	127
Wheat straw	1952-53	5999	7039	8352	5357	7686	8348
Per cent. over control	...	100	117	139	100	143	156
TREATMENTS	**Year**	N_0	N_{25}	N_{50}	P_0	P_{50}	P_{100}
Paddy grain	1951-52	438	607	687	533	560	636
Per cent. over control	...	100	139	157	100	105	119
Paddy grain	1952-53	1220	1135	1115	1249	1124	1098
Per cent. over control	...	100	93	91	100	90	88
Paddy straw	1951-52	1169	1580	2013	1462	1611	1689
Per cent. over control	...	100	135	172	100	110	116
Paddy straw	1952-53	6517	5995	5997	5886	6128	6495
Per cent. over control	...	100	92	92	100	104	110

(N. B. Suffixes after nutrients indicate doses per acre applied to the crop)

TABLE 8

RESIDUAL EFFECT OF FERTILIZERS ON WHEAT CROP FOLLOWING THE PADDY CROP

(lbs per acre)

TREATMENTS	N_0	N_{25}	N_{50}	P_0	P_{50}	P_{100}
Wheat grain	1069	1044	1113	973	1107	1147
Per cent. over control	100	98	104	100	114	118
Wheat straw	3037	3209	3460	3104	3133	3469
Per cent. over control	100	106	114	100	101	112

(N. B. Suffixes after nutrients indicate doses per acre applied to the preceeding crop).

The results obtained in regard to the deficiency of potash in these soils are not yet conclusive although indications are that application of potash as potassium sulphate at 60 lbs K_2O per acre for wheat gives increased crop production.

SUMMARY

The paper illustrates how soil survey and soil classification can be of help in developing and managing scientifically a new reclaimed area for continued agri-

cultural prosperity. Detailed soil survey and soil mapping of one unit of Tarai State Farms, consisting of 5500 acres in the Nainital Tarai of Uttar Pradesh showed the presence of five soil types which differed from one another in soil characteristics, fertility status, agronomic adaptibility and fertilizer requirements. A detailed soil map showing the distribution of these soil types was prepared.

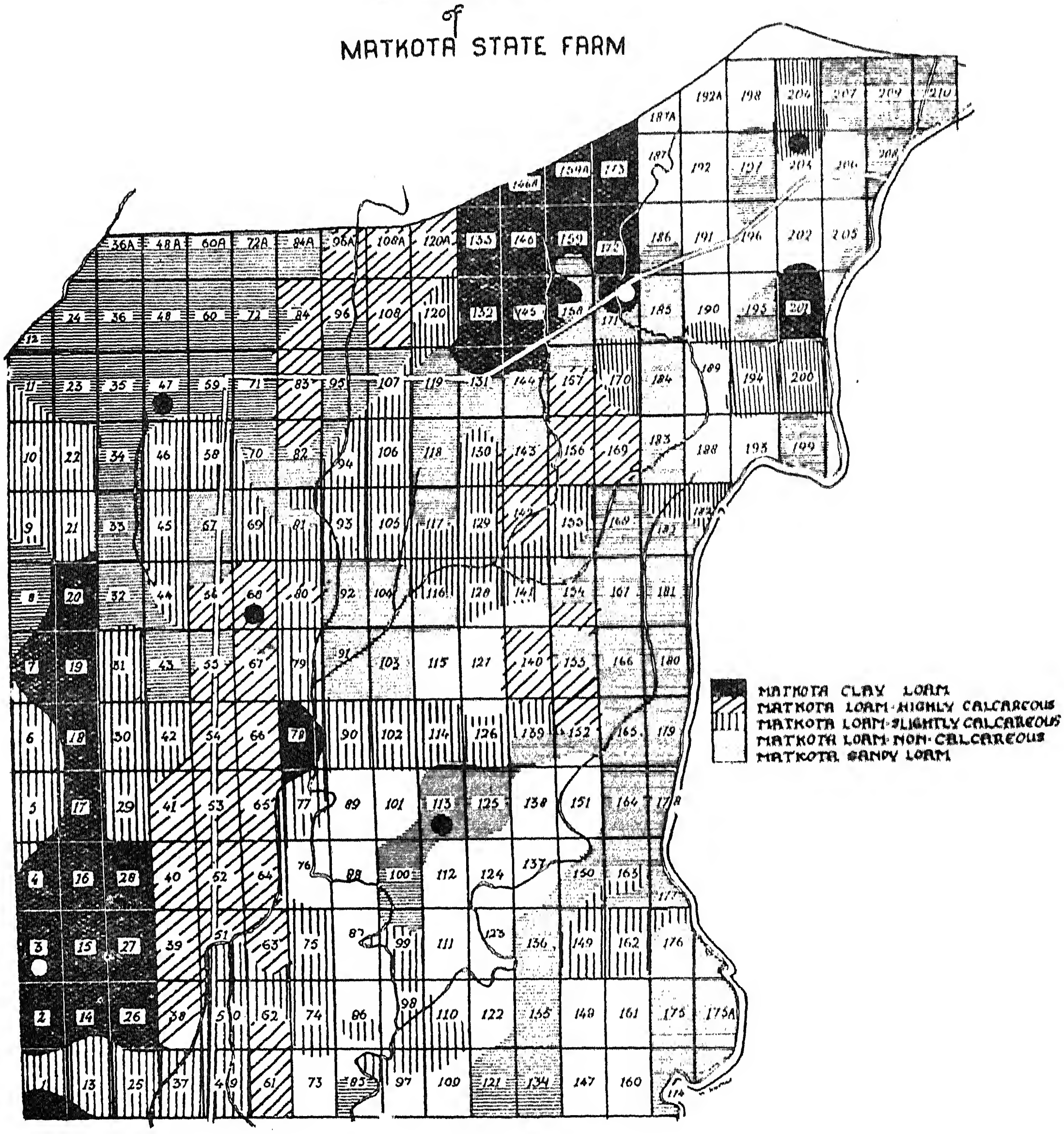
On the basis of the existing information on these soil types recommendations for suitable crop rotations ; water, manure and fertilizer requirements ; and tillage practices for increased crop production and soil fertility maintenance have been given.

The fertilizer requirements, as indicated from soil analysis data, have been verified through field tests conducted on the farm for three years.

ACKNOWLEDGEMENT

The field work reported in this paper was undertaken by the field staff of the Regional Soil Laboratory, Rudrapur (Nainital). Sri A. N. Misra, Assistant Soil Chemist, Rudrapur gave considerable assistance in the collection of agronomic data under fertilizer trials.

SOIL MAP of MATKOTA STATE FARM



EVOLUTION CYCLES OBSERVED IN DESERT FRINGE LAND

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(*Communicated by Dr. S. P. Mitra*)

Soil and land evolution is sometimes conceived as a steady, gradual change, sometimes supposed to conform to self-repetitious, cyclic patterns. Usually such notions are bound to remain rather vague and non-specific, since the time periods involved in evolution cycles are far too long to permit scrutiny, not to mention investigation or speculation as to the causing mechanisms. A notable exception to this seems to be afforded by evolution of sand-desert fringe land; there, short-period alternating border fluctuations of the desert land on one side, and the vegetated land on the other, are known to have taken place during the lifetime of only a few human generations. A quicker-than-normal pace of evolutional cycles in the particular case of sand-desert fringe land should not be surprising, considering the strong opposed influences on such land exerted by the contrasting adjoining areas. Yet, study of evolution there, in view of the lesser complexity of the problem there and of the shorter time-periods involved—is liable to render information relevant to the principles of land evolution in general. In no known case can evolution be considered as a merely on-the-spot, fully self-contained process; it is always largely determined also by the adjoining areas and by the wider environment as the latter influences wind-regime and air-circulation, evaporation, surface and underground drainage, most biological factors, etc.

The author found opportunity to collect information on the pattern of sand encroachment into vegetated land and the re-conquest of the sand tracts by vegetation at two places in Israel; in the south of the country where sand from the Sinai sand-desert is constantly invading pasture land, and more convenient for study along the eastern border of the expanding coastal sand dune belt. The latter locality, especially a drift sand bulge with the ruins of the ancient Roman capital of the country, Caesarea, at its centre and a radius of several miles, provides ample historical, geographical reference data, without which observations could not be fully interpreted. It was possible from those historical records to calculate the long-term (two millenia) average of the sand encroachment rate at that locality which was found to be 7 tons per annum per meter front, or, expressed as annual frontal advance of the sand border line, $2\frac{1}{2}$ meters per annum.[1] The question investigated here was whether this invasion by the sand was taking place at an even, steady pace or whether the sand front advanced in rhythmical, jerky motion.

For this purpose a three mile stretch of the sand tract border line, where it runs conveniently parallel to the railway tracks of the Haifa-Tel Aviv line (between the stations of Benyamina and Hedera) was taken under close observation for a quarter of a century. A telegraph line, running also parallel on the western side of the border, served as excellent reference line not only for detecting lateral shifts of the sand border but also for exact estimation of the changing sand levels (the sand at some places piled up so high that the dune tops almost touched the wires). The basis for all following observations was a careful survey by the local development authority in 1927 (PICA), where the distribution and location of the encroaching sand were mapped. Ten years later the late Professor A. Reifenberg of the Hebrew University measured and recorded the changes of the sand border line that had occurred since. After another 10-year interval in 1947, the present writer re-checked the distribution of the sand noting the advance of

the sand front where it had taken place. Finally, he re-visited the sand fringe again this year to see whether the advance had continued. All visits took place at approximately the same season of the year, namely autumn.

Comparison of those four successive surveys show that the rate of sand front advance had far from being steady, even become reversed, occasionally. It transpired that the average advance velocity for the first of the 10-year intervals had been aimost equal to the aforementioned calculated millenial average, namely 2 meters per annum. But during the second 10-year interval the sand advance had been halted, except at two particular points. The last interval, finally, not fully ten years yet brought with it a pronounced return of the vegetation on to the sand tracts, pressing thus the drift-sand border line back. Reference to the level of the telegraph line showed that this did not imply that sand had ceased to be blown across the border or that even some sand had been blown back ; it merely meant that the rate of sand accumulation had fallen below a critical value so that the incoming sand could be assimilated and stabilised by the vegetation as it came. The plants getting a progressive foothold on the sand fringe were mostly *Artemisia monosperma*, *Retame retam* and *Polygonum equisetiforme* S. The conversion of the sand into sandy soil takes place quickly, by the addition of plant remains to it, of mineral solutions sucked up from the buried soil beneath by deep plant roots, and of dust caught by the aerial parts of the plants.

These findings were confirmed by comparison of aerial photographs, two sets of which were available : one set dating back to World War II when the region was photographed by the RAF ; and one recently photographed set. Unfortunately those two sets were not photographed during the same season of the year, but nevertheless the advance of the vegetation into the sand area could be clearly seen.

General Formulation of Cycle Forming Mechanisms

Examination of local meteorological records shows that there were no corresponding climate fluctuations during those three 10-year intervals, to which the described oscillation of the sand border might have been. It is also evident from results of observations at nearby locations that the rhythm of sand encroachment is not necessarily synchronous at different locations. To explain the phenomenon merely by referring to unspecified ecological factors, which undoubtedly are involved, is not helpful towards a general formulation of the causes of cyclic evolution.

Abstract deliberations lead to the conclusion that no cycles or rhythms may be expected in evolution if it is composed exclusively of processes that maintain a steady rate. If one or more of these processes are of such nature as to diminish gradually with the progress of evolution, the latter will still continue smoothly, though possibly might change slowly its direction. But if one of the processes involved is characterised by a tendency to increase, not gradually but in proportion to its own intensity at a given moment, then one of two things may happen : either this self-accelerating process is so powerful as to override all constraining other factors and thus lead not to evolution but to a single catastrophic event ; or, stabilising factors will be able to prevent the catastrophe before a given stage is reached and thereby cause the force of the self-accelerating process to collapse. After a while the latter again gains impetus by its self-accelerating mechanism and thus initiates a fresh cycle ; which again will repeat itself.

Applying these general notions to the presently discussed problem, which is a relatively simple one, the self-accelerating process is to be identified with the

accumulation of sand. The accumulation of sand is a self-accelerating process in view of the well-known tendency of drift sand to collect where there already exists a collection of drift sand, in preference to collecting on a solid surface ; the higher the existing pile, the more drift sand is induced to collect on top of it.* The constraining force, which prevents the rate of sand accumulation to exceed a given maximum is the natural limitation of supply rate by the wind. Now, as failure of sand supply breaks the self-accelerating mechanism of drift-sand accumulation in the fringe land, vegetation is given a chance to make its inroad onto the mobile sand area ; until some incidental failure somewhere in the vegetational cover triggers off a fresh advance of the drift-sand. In passing it may be pointed out, that at the lull stage, directed human interference could with comparative ease stop the sequence of cycles or change their direction for a large area.

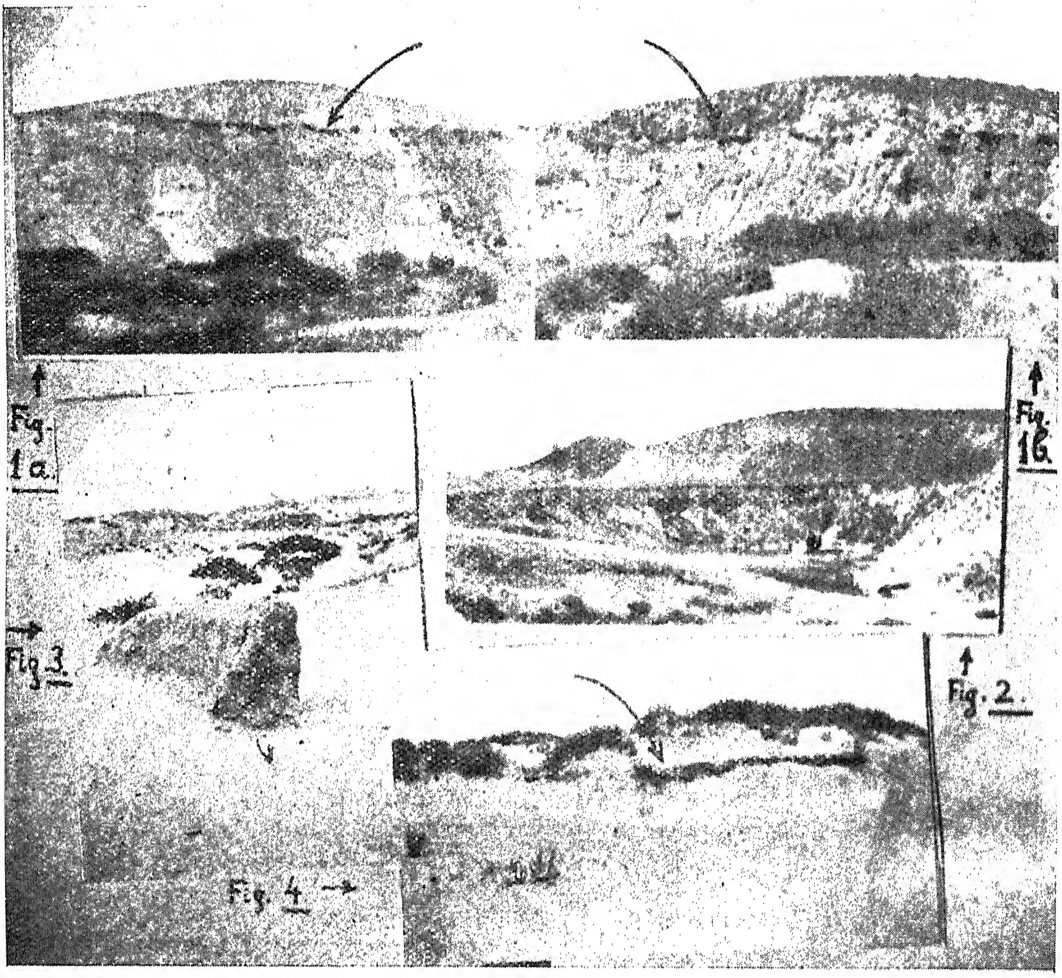
One of the most common, or possibly the most common, self-accelerating process involved in natural evolution is erosion in its many forms. Erosion cycles are therefore predominant in nature, but for reasons to be pointed out in the final part of this article they are harder to study and will be only briefly referred to in this discussion.

Evidence of Cyclic Land Evolution in the Past

The site of the Agricultural College of the Hebrew University of Israel is situated in the midst of an area that is today highly agricultural (producing the biggest share of Israel's citrus crop). One millenium ago this area was still a bare dune sand tract of the same kind as those discussed in the preceding paragraphs are to-day. At the time the Arabs were conquering this country these sand tracts were just slowly beginning to become stabilised. In fact, the central town of this area derives its name from the fact that it was founded by the settling Arabs at a time when the site was still covered with sand : "Ramle" (which means in the Arab language "Sands"). At the same time other tracts of land, that from historical notes are known to have been good agricultural land, have turned into drift sand plains. It is reasonable to see in these changes phases of longer period cycles governed by internal laws similar to the short period cycles discussed before. (The possibility of changes of the natural character of the land owing to the agricultual efforts of the conquering Arab tribes need not be taken into consideration here, since these tribes, neither skilled nor interested in agriculture, hardly were organised to interfere actively with natural evolution : if at all, their interference as herdsmen would have had the opposite effect than the one that took place in the Ramle area).

Cyclic evolution could, admittedly, be more plausible if quantitative predictions regarding the duration of cycles and their phases could be made, unfortunately, only general statements can be made. One of them is, that the kind of cycles discussed here (including erosion cycles) are certainly the quickest of evolution cycles, because their mechanism of operation is mainly mechanical while the commoner kinds are probably predominantly biological. Another statement that can be made is that *cet. par.* cycle duration is most probably directly related to the size of the area affected. Thus, cycles of short-time, local character may have longer cycles of regional character superimposed on them, such as may have been operative in the Ramle area.

*The aerodynamical explanation for this curious behaviour of drift sand is rather complicated. This tendency of drift sand is also what causes mobile sand to form all sorts of undulating surfaces, dunes, tumuli, ripples, etc., instead of being swept smooth and flat by the wind.



On a geological scale the existence of region-wide, long-period cycles may be studied by analysing the assorted sediments deposited by them. Borings and escarpments in the large region of which both areas discussed before are parts show, that the late pleistocene deopsits of this region consist of re-occurring sequences of sediments that are similar to those produced on the surface now. Each sequence is made up of three layers : *top* : laminated, carbonate-cemented sand ; *middle* : red, carbonate-free sandy soil or loam ; and *bottom* : impervious, reduced iron clay-pan. Figs. 1 a and 1 b depict such a sequence as it is revealed along an escarpment in the Ramle area. The "cap" (above the distinct straight dividing line indicated by black arrows) constitutes the top-layer of the sequence ; the middle layer which does not assume any specific shapes such as the "cap" top layer extends in the picture from the line indicated by the arrows down to the bottom of the escarpment ; the bottom layer is hidden in these pictures by the vegetation in the fore-ground. The full sequence can be seen on Fig. 2, which shows the same escarpment in a wider frame ; the excavation below the escarp-

ment shows the depth of the bottom layer and below it the top layer of the next lower sequence which is identical to the upper sequence. At least three such sequences are known on top of each other and are identified with dune "generations" *i.e.* cycles. The mechanism leading to the sortation of the sediments so that a sediment sequence is formed for each "generation" has been studied by the author in detail and published elsewhere [2, 3] *

Occasionally layers of sediments in those sequences are found missing, obviously removed by the interference of erosional cycles. Erosional cycles cannot be studied as easily as the accumulation cycles discussed here since by their very nature they leave no records. The investigator may use, however, morphological indicators. Fig. 3 shows a type of indicator for a completed erosion cycle, which is encountered comonly in sand desert fringe land : a man-sized body of hardened soil that stands isolated on the lowered desert floor. Because of their curious shape these typical figures have been christened "sphinxes" by Walther. "Sphinxes" always face in same direction, namely into the predominant wind, since they owe their existence to the casual presence of some erosion-resistant substance or object (for instance a stone embedded in the former soil) that formes the sphinx' head ; this piece continues to protect the body of the sphinx against erosion by the drift sand. Fig. 4 shows another means of identifying a completed erosion cycle in sand desert fringe land : since the drift sand has a tendency to accumulate in discrete tumuli, even while erosion lowers the level of the land between, former soil horizons and profiles are preserved underneath such tumuli, provided these tumuli don't turn into migrant dunes but are held in place by some vegetation. The black arrow in the picture indicates a portion of a former soil horizon sticking out from underneath the sand. The vegetation clings to the top of the tumulus in preference to the desert floor, since there drift-sand erosion is still in progress. The same distribution of vegetation, indicating the present phase of the erosion cycle can be discerned in the background of Fig. 3.

SUMMARY

Evolution cycles in sand-desert fringe land, where such cycles are comparatively simple to observe and to record are discussed and conclusions relating to the general cause of cyclic evolution attempted. These causes are formulated as being due to the action of self-accelerating processes (erosion, sand accumulation) linked with evolutional factors of a stabilising nature. Information regarding the mode of operation of these factors in sand-desert fringe land was collected by direct measurements, by analysing historical records, and by interpreting deposit sequences of the late Pleistocence. It is suggested that human interference during the lull-phase of a cycle could well change the course of land evolution even on a large scale.

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* The mechanism found to be opertive is not connected with any speculative climatic oscillation during the late Pleistocene.

THE GEOCHEMISTRY OF MADRAS SOILS

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Of the many soil forming factors, climate was considered to be the most important by Russian geologists. The American School of Soil Scientists was influenced to a great extent by the concepts of Russians in this field of investigation. As the vastness of the country was a common factor in both the nations, the point of view of climate was terrible in either instance. In the relatively small area covered by Madras, however, not much useful purpose will be served by looking to climate as an explanation for variation in soil formation, and hence soil scientists working here have been forced, like the British, to seek in the composition of the parent rock as a clue to the spectacular variation exhibited by the different types of soil encountered in a small expause.

The work of the Chemistry Section, Agricultural College and Research Institute, Coimbatore, has been pursued along a number of lines prominent among which are, the study of the general characteristics of the different soil types present, the origin of these soils from rock types, the influence of the property of parent rock on the characteristics of the soil formed, and the classification and comparison of the different soil types.

GENERAL CHARACTERISTICS OF SOIL TYPES

(1) **Origin**. Harrison and Sivan[2] investigated the origin of a number of black soils from areas all over the State and observed that the underlying rock in the case of black soils of Tirunelveli and Ramnad were garnet ferous granitoid gneiss, that the same kind of rock without garnet was observed in Bellary side, other micaceous gneiss was present under Guntur soils and other black limestone occurred under Nandyal soils. Thus the origin was observed to be varied and not specific.

Preliminary work done during 1936-37[6] pointed the conclusion that mineralogical composition of parent rock, rather than climate of environmental factors was of prominent importance in the origin of black and red soils of the State.

The soil survey of the Tungabhadra Project area[18] included a detailed chemical and minerological examination of a number of soil samples from profile pits, as well as samples of underlying rock. Much light has been thrown by this detailed investigation on the origin of black and red soils in contagious areas, and the relationship between the properties of the parent rock and stone of the soils formed.

It had been previously supposed that black soils were formed from red soils, and that the former which were alluvial is found side by side on the Tungabhadra Project area, however, disproves both the above suppositions. The uniformity

of chemical composition, judged from the SiO_2/R_2O_3 ratio for different depths in the same profile, and the accumulation of high proportions of salt at about the third foot in the profile, argue strongly against the alluvial origin theory for the formation of black soils. The occurrence of vast expanses of black soils in elevations lends support to the view that they were formed on the spot, and not transported.

A detailed study of the properties of the black and red soils of the Madras Deccan on the context of their geological associations was made for fixing the origin of these two main types of soils.[7]

The three main types of rocks occurring in the region were collected and analysed. They are (1) Hornblende, granites and gneiss. (2) Micaceous granite and Red granite, and (3) Hornblende Schists (Dharwar age).

The results of complete chemical analysis are tabulated below :

TABLE I

CHEMICAL COMPOSITION OF DIFFERENT TYPES OF ROCKS OF THE MADRAS DECCAN.

Item of analysis	Chlorite Schist (Hagari)	Horn Blende (Berinhal)	Trap (Challa Kurichi)	Horn Blende (Adoni)	Trap (Adoni)	Red granite (Adoni)	Mica Granite Kechen gud.	Mica Granite Horlekota
			TRAP					
1. Silica (SiO_2)	82·24	50·48	50·28	52·54	52·69	71·37	73·84	72·15
2. Alumina (Al_2O_3)	9·36	20·13	18·44	24·35	23·44	14·54	13·76	14·31
3. Iron Oxide (Fe_2O_3)	2·95	9·60	14·24	6·98	8·05	3·49	0·88	3·60
4. Sesquioxide ($Al_2O_3+Fe_2O_3$)	12·31	29·73	32·68	31·33	31·09	18·03	14·64	17·91
5. Lime (CaO)	0·60	10·98	9·64	7·70	9·42	1·54	1·40	1·65
6. Magnesia (MgO)	0·93	4·21	6·01	5·81	5·21	0·42	0·46	0·54
7. Potash (K_2O)	...	0·14	0·17	0·78	1·03	3·83	3·78	4·41
8. Soda (Na_2O)	...	2·23	2·44	3·56	2·74	3·54	4·93	4·21
9. Silica Sesquioxide	2·44	3·26	3·10	3·09	3·17	7·24	8·98	7·72
10. Sp. Gravity	2·55	2 88	2·82	...	...	2·48	...	...
11. Moisture								
12. Loss on ignition.	0·31	0·14	...	...	0·07	0·33	0·64	...

It is seen from the table that the traps (which are related to the traps of Bombay) have a high Ca, Mg, and Na content, and a low K content. The red and micaceous granites have a low Ca content, but a high K, Na content. Granites and gniessies containing hornblende are of frequent occurrence in the tract, this mineral containing high amounts of Ca, Mg and Na and low amounts of K.

As black soils contain high amounts of Ca, Mg, and Na and red soils high amounts of K, but low amounts of Ca, and as the geological associations of black

soils were the traps and granite and genisses containing hornblends and those of the red soils, the red or micaceous granites, it was reasonable to say that the respective geological associations were responsible for the respective soil types produced from them.

To confirm the above hypothesis, the mineralogical composition of the black and red soils of the tract, and their respective parent rocks were studied.[8]

The minerals present were separated by heavy liquid sedimentation and studied under the heads 'Light', 'Medium' and 'Heavy' based on their specific gravity.

ROCK :

(1) *Heavy Fraction.*—The granites underlying black soils contained hornblende, amphibole and pyroxene. Trap rock contained small quantities of mica. In the granites underlying thred soils, illmenite and magnetite occurred in conspicuous amounts. The absence of hornblende in these rocks was a distinguishing feature.

(2) *'Medium fraction'.*—Almost the same minerals were encountered.

(3) *'Light Fraction'.*—Quartz was present in preponderant amounts in both rocks. Microcline and Plagiodose felspars occurred in the black soil rocks. Some levcoxene was observed in red soil rocks.

The main difference apparent in the mineralogical composition of the two rock types was the relative abundance of the ferromagnesium mineral in the 'Heavy' fraction of the black soil rocks and their absence in the red soil rocks and the occurrence of mica in the 'Medium' fraction of red soil rock and its absence in the other type.

SOIL :

(1) *'Heavy Fraction'.*—The abundance of ferromagnesium minerals in the fine sand fractions of black soils and the absence of the same in the red soil separates were the main features in the properties of the two soil types. Although the Iron minerals occurred in both soils, the absence of hornblende augite and pyroxene characterised the red soils and sharply differentiated them from the black.

(2) *'Light'.*—Mica plentiful in the red, and absent in the black soils. Quartz was a common factor for both types.

The similarity in the mineralogical composition of the parent rock and the soil type evolved from it explains in no uncertain terms the mode of formation of the two soil types and excludes completely any view regarding the formation of one from the other type, or the alluvial origin of the black soils.

The relative depths of the black and red soils and other facts in support as it is known that the black soil rocks weather more easily than the red soil ones, and so the depths of soil formed by weathering would be expected to be greater in the case of black soils.[8]

(2) **General properties.** Early investigation[4] into the properties of the soils of Madras State revealed the fact that the black soils are characterised by a high content of total silica (50-54%), CaO and MgO (5-7%) and low sesquioxide (28%). Red soils were relatively poor in silics (45%), very poor in CaO and MgO

(0-6%) and richer in Iron and Alumina (40%). Laterite soils were poorest in total silica (35%), almost devoid of CaO and MgO and richest in sesquioxide.

It was also observed that black soils possessed a high exchange capacity and exchangeable Ca, K values and that these decreased with depth, while the exchangeable Mg and Na values increased.

A detailed study of base exchange in the soils of the State[5] showed that black, and alluvial soils had high exchange capacities, while the others had only low values. It was also found possible to classify the soils of the State into broad groups according to their silica sesquioxide molar ratios of their clay fraction, and that this classification was identical with the one employing the base exchange capacity.

(3) **Colour.** Harrison and Sivan[2] after studying the many local variations of the black soils occurring in the State came to the conclusion that Annentt's[1] explanation that the colour of the black soils was due to the presence of titaniferous magnetite was not capable of universal adoption with reference to the black soils of the State, and observed that the black colour was due to a colloidal, hydrated silicate of iron and aluminium and also to an organic compound of iron and aluminium.

Ramaih and Raghavendrachar[3] made an intensive study of the influence of organic matter on the colour of black and red soils, taking typical black and laterite soils from Guntur and Taliparamba respectively for their investigation. They conclude that it is the quality rather than the quantity of orgnic matter present, tnat counts, and attributes the deep black colour to the combination of organic matter with a clay complex of high SiO_2/R_2O_3, and high Ca and Mg content, even though a larger amount of organic matter is present in the red laterite soils, the mode of combination is different, and so only the brightness of the red colour is diminished.

II. STUDY OF ZONAL TYPE

Black and red soils from profile pits in contiguous areas in Coimbatore taluk[9] were studied. A study was undertaken to throw light on the strange phenomenon of the occurrence of black and red soils in close proximity, without the corresponding occurrence of climatic or environmental factors to account for it.

(1) *General Properties of Soils.*—The study revealed the fact that[1] the black soil in Coimbatore Taluk is a heavy clay, whereas the red ones collected from adjacent areas were loamy.[2] The black soil retains more moisture than the red, and[3] contains more $CaCO_3$ and organic carbon (by wet digestion).[4] They holds more water soluble salts, especially Na, Ca and Mg sulphates and NaCl and has a higher hydrogen ion concentration.

(2) *Clay.*—The chemical analysis of this fraction showed that in black soils, the insolubles, CaO, combined SiO_2, Na_2O, silicate of calcium, SiO_2/Al_2O_3 and SiO_2/R_2O_3 were high and R_2O_3 and MgO low.

(3) *Fine silt.*—Analysis of this fraction showed high amounts of matter lost on ignition, total SiO_2, total CaO, MgO, Na_2O and less of R_2O_3 and K_2O in black soils.

(4) *Fine Sand.*—Black soils were shown to contain higher amounts of silicate of calcium, and smaller amounts of K_2O than the red soils, with reference to this fraction.

Fusion analysis.—The fine sand in black soils showed that compared to red soils, the amount decomposed by extraction with Con HCl was higher. This probably indicates the presence of chloride, or lime felspar in association with black soils, and of amphiboles aad phyroxenes in red soils.

Base exchange.—The base exchange capacity of black soils was observed to be about twice that of the red soils. Calcium in the exchangeable and silicate forms was present in larger amounts in black soils.

(5) *Dehydration curves.*—Those of the black soils resembled that of scolecite (a Ca zeolite) and those of red soils, that of Cecil clay.

In conclusion it might be stated that the analytical data indicate that while both the black and red soils are dedrived from Archaean gneisses and granites, the former are derived from calci magma and the latter from alkali magma.

2. BLACK AND RED SOILS FROM THE UDAMALPET AND GOBICHETTIPALYAM AREAS.

(1) *Udamalpet.* The clay fraction contained high amounts of silicate of calcium, almost completely in the exchangeable form. Mineralogical examination showed that in black soils the Ca existed mostly as carbonate and seldom as silicate. In red soils Ca and Mg carbonates were formed moslty in lower layers. Hornblende was in higher amounts in black soil, and leneoxene in higher amounts in red soils. The dehydration cuive for black soils resembled that of scolecite (a calcium zeolite) and that for red, the curve for kaolin.

(2) *Gobichettipalayam.* The red soils of this tract are found to originate from calcium amphiboles indicating that even rocks containing calcium silicate, in absence of Na, decompose into red soil and $CaCO_3$, as $CaCO_3$ by itself will not bring about the high pH required for black soil formation. It was observed that the SiO_2/R_2O_3ratios were governed by pH during soil formation.

(3) *Black and red soils formed on limestones of the cuddapah Kurnool formation near Jammalamadugu, Tadpatri and Nandikotkur.* The Jammalamadugu limestone was black and the Nandikotkur red and highly compact. Decomposition with cold 1% HCl showed that the non-limestone portion in the Jammalamadugu black limestone was only 18·38% and that the higher value of 38·69 was obtained for the corresponding fraction of the Nandikotkur red limestone ; this fraction consisting mainly of quartly and clay.

TABLE II

RESULTS OF ANALYSIS OF BLACK AND RED LIMESTONE FROM CUDDAPAH KURNOOL FORMATION IN PERCENTAGE

Items of *Analysis*	Red limestone *Nandikotkur*	Black limestone *Jammalamadugu*
(1) Matter insoluble in hot conc. HCl.	85·12	82·22
(2) Fe_2O_3 and Al_2O_3	8·94	11·86
(3) Loss on ignition	3·66	3·30
(4) Other bases by (difference)	2·28	2·62

The HCl insoluble residue from the Nandikotkur limestone contains more of sesquioxides and less of acid insolubles, while that of the black Jammalamadugu limestone contains less sesquioxides, and more of acid insolubles.

(4) *Black Soils Formed from Cretciceous Formation in the ariyalur Tirhchirapalli area II.* The black soils were similar in salt content and pH to other soils of the same type occurring elsewhere in the State.

(i) *Moisture relationship.* The dehydration curves for both black and red soils were alike up to 50 C. Red clay had a lower moisture absorption capacity than black soils was more due to the moisture of clay than the absolute clay content.

TABLE III

DEHYDRATION VALUES FOR A CLAY SAMPLE ARIYALUR BLACK COTTON SOILS

Allinagaram Pit (First foot)

Temperature °C.			*Moisture Loss.*
100	...	...	12·79
150	...	...	14·19
200	...	...	17·21
300	...	...	17·91
350	...	...	18·44
400	...	...	20·30
450	...	...	21·02
500	...	...	22·18
550	...	...	23·16
600	...	...	23·16

The curve obtained from these figures resembles that of montmorillonite and show that the black soils of Madras though derived from different geological formation, are similar in properties.

(ii) *Geological Association*[12]. The acid soluble aluminium, Fe and Ca, SiO_2/Al_2O_3 and SiO_2/R_2O_3 of the black soils of the areas were similar in magnitude to those of black soils formed from the other formations in the State, *viz.* granites and gneisses schists, Dharwar and Cuddapah and Kurnool shales and limestones.

(iii) *Minerological Examination.* The sand fraction of the black soils contained about 90% quartz with opaque iron minerals, sphene and some garnet. The quartz grains were round showing the sedimentary origin of the parent material.

(5) *Black and Red soils from the Azixnagar area, South Arcot District.*[15] This area has a plentiful supply of artesian springs, and contains some lignite deposits also. The red soils occupy only a smaller area and are derived from Cuddalur formation. The black soils resemble in many respects the black

cotton soils found elsewhere in the State. Peculiar features are their lower content of organic matter and consequent light black colour and their phenomenal depths. Borings are said to have descended upto[1].60' Minerological examination of the sandy fractions reveals the presence of rounded quartz grains, hinting at the sedimentary nature of the origin of these soils. Amphiboles, pyroxenes and titanium minerals usually encountered in other black soils varieties are absent here. The soils are surmised to be sedimentary deposits, probably of marine origin and of Cretaceous or Cuddalore age.

(6) *Black soils of Jammalamadugu*[15]. The clay impurity present in the limestones occurring here was found to be montmorillonitic and kaolinitic and observed to give rise to black and red soils. The nn-calcareous residue from the Jammalamadugu limestone was black. The organic matter in this was easily oxidised, hinting at cambrian or post-cambrian origin.

(7) *Black soils of Hasanur*[15]. The black soils occurring here are interesting in that that they are found at the high elevations and in mountainous topography, but have most properties in common with similar soils occurring in the plains. They contradict the older theory accounting for black soil formation by washing down from higher altitudes. The striking difference was in the low pit which is attendant on the high organic matter content. The black colour was destroyed by treatment with H_2O_2, without any initial dilute acid digestion.

(8) *Red soils of Tirunelveli*[15]. Some deep red soils from the Tirunelveli, Ambasamudrum, Nanguneri, Tenban Taluks of the Tirunelveli District were studied to observe any departure in properties from other red soils. These were apparently derived bearing from garnetiferous acidic granite of the western ghats, biotite and iron amphiboles and pyroxenes present in the parent rock contributed to the deep red colour of these soils. The clay was kaolinitic and the SiO_2/R_2O_3 ratios were of the same magnitude as for other red soils found elsewhere in the State.

(9) *Red soils of Saravanampatti* (*Coimbatore Dt.*) Hosur and Hindupur and their geological association : (*i*) Sravanampatti : Quartz hametite rocks were responsible for the formation of red soils in this tract.

(*ii*) Hosur : The soils are deep red in colour and trace their origin to the acidic, gray weathered gneisses in the area, which contain pinite felspars. The soils formed are sandy and gravelly.

(*iii*) Hindupur : The red soils represent in association with kankar, and are brownish in colour.

(10) *Red soils of the Lower Bhavani Project area.* The parent rock is schistose geneiss, containing quartz, felspar, muscovite limonite, talc, granite, serpentine, calcite, and magnetite. The red soils formed from these are shallow, and are coarse in texture.

(11) *Allvuial soils of Villupuram.*[16] The soils are coastal alluiva, resembling the black soils. More than 75% is made up of the sandy fraction. The top soils is black, but the sub-soil is yellowish black. When the top soil is treated with N/5 HCl, and then with H_2O_2 the residue acquires the colour of the sub-soil. In this respect these soils behave like other black soils of the State. Quartz, microcline felspar, pyroxene and leucoxene are met with in the fine sand fraction. The alluvial origin of the soils is indicated by the round quartz grains.

(*12*) *The laterites of nileshawar.*[14] The soils belonging to the Agricultural Research Station, Nileshwar differ from the typical laterite in some respects. Profile studies suggest a marine origin of the soil. Shales' have been very often encounted in the sub-soil and are so plentiful as to meet the local requirement of burnt lime.

TABLE IV

	Nileshwar	Taliparamba
(1) Loss on ignition	13·19	18·23
(2) Silica (SiO_2)	41·28	33·98
(3) Alumina (Al_2O_3)	33·26	31·86
(4) Ferric oxide (Fe_2O_3)	10·47	16·41
(5) Lime (CaO)	0·063	

The above table show the chief constituents of the Nileshwar clay compared with corresponding areas of the Taliparamba clays which can be taken to represent a typical laterite. It will be observed that the Nileshwar clay contains higher amounts of the explanation for the yellow colour of the soils in this tract. The higher value for SiO_2 places the soils in the laterite group of soils and excludes them from the true laterite group.

(*13*) *The soil types of the Kollegal tract.*[17] (*i*) Alluvial soils :—The paddy lands under the big tanks are alluvial in origin as indicated by the underlying bed of sand.

Gneisses, of varying minerological composition with dykes and veins of of amphibolites constitute the geological formation in the area.

(*ii*) Black soils :—These resemble the other black soil of the State, but are highly clayey, containing more than 80% of fine fractions.

Magnetite and alkali felspar are conspicuously absent in the fine sand fractions of the black soils. The rounded form of the quartz grains, and the presence of concretionery gravel made up of ferugenous calcium cabonate and organic matter point to the alluvial origin of the black soils occurring here.

Chemical analysis reveals the fact that the black soils present in this area differ from those present elsewhere in containing high amounts of unweathered silicate minerals like felspar and hornblende.

SUMMARY

(1) The importance of the role of parent rock in determining soil type has been stressed.

(2) The probable origin of black and red soils from similar rocks of different mineralogical composition has been inferred from a detailed study of the soil profiles in the Tungabhadra Project area.

(3) The general characteristics of the soils of the State have been investigated and the usefulness of SiO_2/R_2O_3 and base exchange capacity in characterising soil types pointed out.

(4) A possible explanation for the colour of the black and red soils has been put forth.

(5) The different soil types encountered round about Udamlpet Gobichetti-palayam, Ariyalur, Jammalamadugu Nandikotkur, Aziznagar, Hasanur, Triuneveli Sravanmpatti, Lower Bhavani Project area, Villipuram, Nileswar and Kollega have been described in detail and their individual peculiarites point out.

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SOIL CLASSIFICATION IN RELATION TO AGRICULTURAL DEVELOPMENT

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It has now been recognised that crop planning and maximisation of agricultural yields should be based on soil conditions. The recognition of the importance of soil to crop husbandry has come about due to the realisation that further progress in securing phenomenal increases in yield by breeding and selection of crops can only be possible by the improvements in cultural practices. The methods of proper crop rotation, manuring and irrigation must now be largely relied upon for improving yields; and soil conditions have to be studied in detail to base the measures of yield improvement on scientific lines.

In pedological sense, a soil should have certain well defined and almost rigid attributes, and all the earthy material on which crops are grown is not necessarily soil. In this sense some of the fresh alluvial soils and the soils on terraced flats and aprons cannot be considered as soils. For those who are engaged in soil survey work for the purpose of crop improvement, soils should be characterised not only by their inherent attributes but also by those properties that have subsequently been acquired by them through human activity. Thus characteristics on the basis of which soils are classified in pedological sense have to be extended and supplemented, so that one may fully comprehend the soil as it is obtained in the fields. It is clear that the pedological classification, evolved as a result of studies of soils, 'unsullied by the hand of man,' is too inadequate to classify all the soils of our fields. Besides, the parameters of the attributes on the basis of which soils of temperate parts of the globe are classified are insufficient to fully characterise the soils of the tropics. Soil structure is an instance to the point. Under temperate conditions due to slower oxidation of organic matter the soil structure is well-defined and fully developed. The soil structure met with under Northern India conditions, for instance, is only weakly developed. The colour intensity is dependent on the moisture content of soils and the same soil under different degree of desiccation or moisture level may give different intensities of colour. This feature of tropical soils is not obtained in the temperate countries where rainfall is more or less uniform in different months and the soils are not subject to that degree of drying as is usual in the dry summers of the tropics. Stability of soil aggregates against impact of tropical rains is one of the important factors for evaluating agricultural characteristics of the soils, and in any soil classification this fact should also be taken into consideration. The actual colour of individual soil aggregates in our climate is masked by the colour of the cementing material. The field behaviour of soils towards crops, manures and irrigation water in alluvial basins and in Bundelkhand region in U. P. indicates that the limits of particle size generally adopted for characterising soils as sandy loam, loam, silty loam, clay loam and clay in temperate countries are not applicable to the local conditions. All these features of soil morphology must be taken into consideration in the characterisation of the soils of the tropics, hot temperate and humid tropic. The examples cited above are merely illustrative and by no means exhaustive. It may be seen that there is considerable scope for a measure of pioneering work in soil systema-

tics, and one should be circumspect in applying *in toto* the experience gained in soil work in the temperate regions to the conditions obtained in India. The more fundamental principles already learned would, however, be useful.

The soils can be classified according to their inherent characteristics as well as in relation to a particular purpose, *e.g.*, agricultural development, afforestation, road making, soil conservation, etc. In genetic classification the relative significance of the soil characteristics—both internal and external is equal. The significance of the characteristics in an interpretive classification varies according to the requirements of the object. In order that it may truly reflect both qualitatively and quantitatively crop responses, an interpretive soil classification must also have a dynamic character and must crystallise the detailed interactions of pedogenic and human factors in the make up of the soil profile. A classification based on the detailed study of the soil profile has of necessity a scientific value besides being practical in application. A dynamic classification is also then necessarily genetic, but a genetic classification need not invariably be based on dynamic considerations. If the soil type is to fully express itself as a factor determining crop adaptibility, it is necessary that all profile characteristics are assigned a place appropriate to their relative significance to crop. A well conceived grouping must be based on differentiating chracteristics which are important for the objective and carries the greatest possible number of co-varying accessory factors that are also equally important for the purpose. According to their relative importance the soil characteristics should be considered at the different category levels. The differentiating characteristics should consist of all those morphological, chemical, physical and biochemical characteristics of soil which are significant for crop growth and development. At each category level the soil characteristics should be divided into a number of homogenous classes relevant to the objective. At the lowest category level the accuracy of observation is high but the number of statements that could be made in relation to the objective is low. At higher category levels the number of statements that could be made are high although due to a number of co-varying accessory factors, the accuracy of the statements would be of a low order.

It is by no means an easy matter to assign specific positions to soil characters at different category levels. There is no great difference of opinion in respect to higher category levels of 'order,' 'sub-order,' and 'great soil groups'. At the level of 'soil order', all soils may, according to the system adopted in the United States, be divided into 'zonal,' 'azonal,' and 'intrazonal' soils. Every soil feature utilised as differentiating characteristic should have a 'ceiling' of independence above which it cannot be used to differentiate without separating like things in categories below it. The halomorphic and hydromorphic characteristics, as are well known, often develop due to orographical and hydrological conditions : for instance, *solanchak* formation is often met with in the Ganga and Jamuna flood basins as well as in association with zonal soils. The same might be said about all the different varieties of *Wiesenboden* or meadow soils, bog soils and the so-called ground-water podzols and laterites. To avoid confusion at the lower category level, it would be better to classify all soils in any locality into two groups only: *viz.*, 'zonal' and 'azonal' soils. The zonal soils are characterised by well differentiated horizons and by profile characteristics, markedly different from each other in conformity with ecological and climatic conditions of the area..

There is considerable room for difference of opinion in respect to the contents of the next level of differentiation, namely, at the 'sub-order' level. It

is, at this point, that all climatic and ecological factors are taken into account. According to some authorities the nature of parent material should also be taken into consideration at this stage. Such a course is particularly necessary in order to be able to find explanation for the presence of soils outside the climatic and ecological zones where they normally occur; such as the presence, for instance, of grey-brown podsolic soils of the Northern Europe; in the hot, humid low-land forests of Assam; and the occurrence of soils resembling reddish brown laterites of the humid tropics with which the workers of India are well acquainted in the plains of Central Virginia in the U. S. A. and Yangtse Valley in Central China. Much of the confusion in soil taxonomy has arisen by mistaking processes for names. The word 'podsol' should not connote any more a formation of ashy-grey soils of Russian conifer forests, but a pedological process mobilising sesquioxides and forming illuvial zones containing free hydrated oxides of iron and alumina. The process may give rise to the well-known podsols or because of topographical and hydrological conditions may lead to stabilisation at some intermediate point. Bucannun gave the name 'laterite' to a sesquioxide-rich soil crust, used in road making in South India. The soils containing these bodies were designated as laterites; but the process of laterisation is by no means confined to the locality where the particular soil formation was first encountered. With the elucidation of the nature of the process giving rise to eluviation of silica and alkaline bases from the soil surface, it is now found that it would not be correct to characterise even the original soil of Bucannun as a laterite. Much of this type of confusion could be avoided by taking the parent material into consideration at category level of sub-order. The variants at this category level should then be the factors of climate, ecology and parent material. Workers in pedology do not seem to have reached even now any agreement in respect to the great soil groups. The U. S. A. Division of Soil Survey recognised 18 great soil groups in that country as zonal soils, 14 under intrazonal, and 3 under azonal. Prescot recognised 28 great soil groups in Australia, nine of which have no parallel in the great soil groups suggested by the workers in America. Van der Merwe has established in South Africa four great soil groups. Every soil survey report contains a few new names for altogether new great soil groups. The 'type species,' as all recent studies show, represent only a point in the population curve and therefore does not represent the features of the population itself. The possibility of finding new 'type species' is therefore, infinite. Unless the names represent concept of soil formation a great deal of confusion is in store for all. What is necessary at present is to correctly define the attributes of the process at the level of great soil groups. For a variety of reasons soil taxonomy is yet in a fluid state and undue importance should not be given to names of great soil groups in preference to the nature of processes which they represent. For the sake of the objective the soils should be classified not only in terms of their own inherent and acquired characteristics, but also according to their behaviour and capabilities. The behaviour and capabilities are not necessarily determined by the differential characteristics but also to a certain measure by the accessory factors associated with each class division of the soil category. Hence arises the necessity of classifying soils into soil families, soil series, soil texture and soil phases.

IMPORTANCE OF VARIOUS SOIL PHASES

Variation in slope, degree and type of erosion, content of stones and pebbles, thickness of alluvial deposits, extent of water-logging, salinity and alkalinity are generally considered under soil phases. Similarly, in some cases the organic

matter content of soils, particularly if it is due to dynamic causes like human activity and application of manure and fertilizer may be grouped under soil phases. All these factors are immensely important for understanding crop behaviour and soil capabilities. Basu in India, Hardy in Trinidad and several other pedologists have considered the drainage condition of soils at a category level of soil series, while others have considered the drainage character at the category level of soil phases. The halomorphic characteristics of soils according to workers in the U. S. A. should be considered at the category level of great soil groups. The phenomena of salinity and alkalinity are observed generally in areas where ground water approaches the surface and are found in association with a variety of soil types.

All parts of the earth conditioned by geological formation of the past epochs by the regime of ground water and by cultural operations like irrigation with salty water find expression to varying degrees in the processes of salinization and desalinization. Alkali soils have been found in Codwell loams of Idaho, Gypseous clay loams at Utah, in Ukraine and in islands in Gulf of Finland, apart from their general occurrence in arid tropics. These soils have been found by Basu in association with immature tropical cherozems, by the writer in Bundelkhand Type III soils as well as in old alluvial flats and in fresh alluvial soils of river basins. Prasad found these soils extensively in North Bihar in association with zonal soils. For these reasons, I consider it more appropriate to include these soils under soil phases particularly where the source of salinity and alkalinity are the character and contents of the ground water. On identical consideration all halomorphic and hydromorphic characteristics could be grouped under soil phases, since they are by no means specific character of any of the zonal groups. All soil characteristics acquired by a soil profile, due either to some accidents or by human endeavour, could appropriately be considered at the category level of soil phases. Soil behaviour towards crops is largely determined by the soil phases. By their nature soil phases can be considered both qualitatively and quantitatively. Salinity, alkalinity, water-logging, etc. are qualitative variants; but their extent can be both qualitative and quantitative. Quantitatively these may be classified, for instance, into low, medium or high; or quantitatively according to the percentage of salinity, etc. Whether a quantitative or qualitative method should be used may be determined by the objective for which soil survey is conducted. The salt tolerance of cereals like wheat and barley are low, while the sugarcane is fairly resistant. Satisfactory growth of wheat cannot be obtained when the salt content is over 0·3 per cent. but sugarcane can grow well even when salt content is over 0·5 per cent. Thus for wheat less than 0·1 per cent. salts is low, 0·1-0·3 per cent. medium and over 0·3 per cent. high. For sugarcane less than 0·3 per cent. salts is low, 0·3-0·6 per cent. medium and over 0·6 per cent. high. The quantitative and qualitative class intervals will be determined by the requirements of the objective at the level of classification of soil phases. A quantitative classification would have a wider application than the qualitative, and soil survey being of wider application, the quantitative aspect should only be considered.

EROSION PROCESSES AND THEIR EFFECT ON SOILS

It is well known that due to the normal erosion process several different but related soils are formed from the same parent material. High lands may have skeletal soils which may be sandy or containing too many gravels or stones or secondary ferrugenous crusts. At the depressions the soils may be of very fine

texture containing colluvial-eluvial products of degradation from high elevations. The slope conditions would determine not only the character and sequence of horizons but also their three dimensional extent. Thus at series level it would be useful to consider slope and erosion conditions and catenary characteristics. It may be seen that under the system followed in the U. S. A. no quantitative limits can be given to soil classes at series level and may to that extent detract much, from the usefulness of soil survey to other objectives, apart from the one for which so much of work is conducted.